PROCEEDINGS

OF THE

AMERICAN ASSOCIATION

FOR THE

ADVANCEMENT OF SCIENCE.

NINETEENTH MEETING

HELD AT

TROY, NEW YORK,

AUGUST, 1870.

CAMBRIDGE:

PUBLISHED BY JOSEPH LOVERING.

1871.

EDITED BY

JOSEPH LOVERING,

Permanent Secretary.

CAMBRIDGE:
PRESS OF JOHN WILSON AND SON.

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OFFICERS OF THE ASSOCIATION

AT

THE TROY MEETING.

WILLIAM CHAUVENET, *President.**
T. S. HUNT, *Vice-President.*
JOSEPH LOVERING, *Permanent Secretary.*
C. F. HARTT, *General Secretary.*†
DR. A. L. ELWYN, *Treasurer.*

STANDING CO MITTEE.

EX-OFFICIO.

WILLIAM CHAUVENET,	J. W. FOSTER,
T. S. HUNT,	O. N. ROOD,
JOSEPH LOVERING,	O. C. MARSH,
C. F. HARTT,	A. L. ELWYN.

AS CHAIRMEN OF THE SECTIONAL COMMITTEES.

F. A. P. BARNARD,	ASA GRAY.

FROM THE ASSOCIATION AT LARGE.

E. D. COPE,	H. B. NASON,
J. E. HILGARD,	JOHN TORREY,
E. N. HORSFORD,	ALEXANDER WINCHELL.

* In the absence of the President, the Vice-President occupied the chair.
† Mr. Hartt being absent, his place was filled by Mr. F. W. Putnam.

LOCAL COMMITTEE.

John A. Griswold, *Chairman.*
George C. Burdett, *First Vice-Chairman.*
P. V. Hagner, *Second Vice-Chairman.*
Benj. H. Hall, *General Secretary.*
H. B. Nason, *Corresponding Secretary.*
Adam R. Smith, *reasurer.*

E. W. Arms,
Miles Beach,
E. W. Boughton,
Irving Browne,
Henry Burden,
J. A. Burden,
E. Corning, Jr.,
David Cowee,
G. H. Cramer,
Charles Drowne,
C. E. Dutton,
William Fenton,
J. L. Flagg,
James Forsyth,
J. M. Francis,
J. W. Fuller,
E. T. Gale,
Uri Gilbert,
H. Gnadendorff,
Hannibal Green,
Robert Green,
C. O. Greene,
Dascom Greene,
Chester Griswold,
William Gurley,
James Hall,
W. H. art,
J. C. Heartt,
J. S. Heartt,
A. L. Holley,
C. R. Ingalls,
A. G. Johnson,
G. B. Kellogg,
Justin Kellogg,
William Kemp,
J. S. Knowlson,
J. H. C. Lajoie,
F. B. Leonard,
H. C. Lockwood,
C. McMillan,
M. L. Marks,
G. W. Maynard,
G. G. Moore,
A. B. Morgan,
G. P. Ogden,
J. B. Parmenter,
C. E. Patterson,
J. B. Pierson,
A. E. Powers,
J. R. Prentice,
D. Robinson,
J. Romeyn,
H. Rousseau,
W. P. Seymour,
W. A. Shepard,
N. B. Squires,
G. H. Starbuck,
F. S. Thayer,
W. A. Thompson,
James Thorn,
Dudley Tibbits,
C. W. Tillinghast,
M. I. Townsend,
J. I. Tucker,
D. T. Vail,
S. M. Vail,
M. R. Vincent,
R. H. Ward,
G. B. Warren,
J. M. Warren,
S. E. Warren,
W. P. Warren,
D. A. Wells,
H. B. Whiton,
L. Wilder,
J. H. Willard,
W. H. Young.

OFFICERS OF THE SECTIONS.

SECTION A.

F. A. P. Barnard, *Chairman.* G. W. Hough, *Secretary.*

Sectional Committee.

G. W. Maynard. Elias Loomis. S. D. Tillman.

SECTION B.

Asa Gray, *Chairman.*
Henry Hartshorne, *Secretary* up to the 3d day.
Theodore Gill, *Secretary* for the rest of the session.

Sectional Committee.

James Hall, J. G. Morris, Alpheus Hyatt.

SUB-SECTION C OF SECTION A.

S. S. Haldeman, *Chairman.* R. H. Ward, *Secretary.*

SUB-SECTION D OF SECTION B.

Thomas Hill, *Chairman.* W. H. Dall, *Secretary.*

SPECIAL COMMITTEES.

A. Committees continued from former Meetings.

1. *Committee to report in Relation to Uniform Standards in Weights, Measures, and Coinage.*

F. A. P. Barnard,
John F. Frazer,
Wolcott Gibbs,
B. A. Gould,
Joseph Henry,
J. E. Hilgard,
John LeConte,
H. A. Newton,
Benjamin Peirce,
W. B. Rogers,
J. L. Smith,
John Torrey.

B. New Committees.

1. *Committee to audit the Accounts of the Permanent Secretary and the Treasurer.*

H. L. Eustis,
Henry Wheatland.

2. *Committee with whom the Permanent Secretary may advise in regard to the Publication of the Troy Proceedings.*

Elias Loomis,
Alpheus Hyatt.

3. *Committee to act with the Standing Committee in Nomination of Officers for the Indianapolis Meeting.*

Section A.	Section B.
G. W. Hough,	W. H. Dall,
A. M. Mayer,	E. A. Dalrymple,
Henry Morton,	E. S. Morse,
S. D. Tillman.	J. H. Rauch.

4. *Committee to arrange for a Meeting of the Association in San Francisco in* 1872.

William B. Ogden,	Charles F. Choate,
Oakes Ames,	James Hall,
John D. Perry,	Samuel M. Felton,
Benjamin Peirce,	J. W. Foster,
Edmond Crocker,	George W. Cass,

Joseph Lovering.

5. *Committee to memorialize Congress on the Importance of establishing an Observatory on the highest part of the Pacific Railroad.*

J. E. Hilgard, Joseph Henry,

J. H. Coffin.

OFFICERS OF THE INDIANAPOLIS MEETING.

Asa Gray, *President.*
George F. Barker, *Vice-President.*
Joseph Lovering, *Permanent Secretary.*
F. W. Putnam, *General Secretary.*
W. S. Vaux, *Treasurer.*

Standing Committee.

Asa Gray,
George F. Barker,
Joseph Lovering,
F. W. Putman,
T. S. Hunt,
C. F. Hartt,
A. L. Elwyn,
W. S. Vaux.

Local Committee.

Daniel Macauley, *Chairman.*
Thomas McIntire, *First Vice-Chairman.*
John C. Wright, *Second Vice-Chairman.*
T. B. Elliott, *General Secretary.*
E. T. Cox, *Corresponding Secretary.*
F. A. W. Davis, *Treasurer.*

D. S. Alvord,
Fielding Beeler,
W. A. Bell,
J. Bernard,
D. M. Berry,
J. J. Bingham,
Elder Black,
James Braden,
William Braden,
R. J. Bright,
A. H. Brown,
R. T. Brown,
Valentine Butsch,
W. W. Butterfield,
John W. Byrkit,
W. B. Chamberlain,
John Coburn,
John Collett,
W. B. Fletcher,
Benjamin Franklin,
Allen Furnas,
Edward C. Garlick,
J. M. Gaston,
David Gibson,
L. W. Hasselman,
T. A. Hendricks,
B. C. Hobbs,
Isaac Hodgson,
John H. Holliday,
Milton B. Hopkins,
P. G. C. Hunt,
N. A. Hyde,
Nathan Kimball,
Edward King,
Thomas D. Kingan,
M. M. Landis,
F. S. Newcomer,
John S. Newman,
W. H. L. Noble,
W. R. Noffsinger,
J. Palmer,
Charles B. Parkman,
Theophilus Parvin,
J. A. Perkins,
S. E. Perkins,
Winslow S. Pierce,
Joseph Poole,
A. G. Porter,
Dillard Ricketts,
A. L. Roache,
Frederick P. Rush,
James B. Ryan,
G. A. Schmitt,
Horace Scott,

Local Committee (continued).

J. A. Comingore,
Robert Connelly,
Thomas Cottrell,
Carlos Dickson,
Norman B. Eddy,
H. A. Edson,
John R. Elder,
W. H. English,
John Fishback,
W. P. Fishback,
E. T. Fletcher,
S. Fletcher, Jr.,
M. G. Lee,
G. M. Levette,
Erie Locke,
John M. Lord,
Nicholas McCarty,
J. E. McDonald,
David Macy,
V. T. Malott,
George Merritt,
T. A. Morris,
John W. Murphy,
John C. New,
A. Seidensticker,
Thomas H. Sharpe,
J. C. Shoemaker,
A. C. Shortridge,
J. E. Simpson,
George W. Sloan,
John S. Spann,
Thaddeus M. Stevens,
J. George Stilz,
C. F. R. Wappenhaus,
William H. Weeks,
William D. Wiles,
J. H. Woodburn.

Local Sub-Committees.

On Reception.

R. J. Bright,
Jno. W. Murphey,
A. H. Conner,
A. L. Roache,
Wm. D. Wiles,
L. W. Hasselman,
E. B. Martindale.

On Finance.

John Fishback,
Austin H. Brown,
E. C. Garlick,
John S. Newman,
A. G. Porter,
Jas. B. Ryan,
N. B. Eddy.

On Lodging and Entertainment.

George Merritt,
J. George Stilz,
John M. Lord,
J. M. Gaston,
Fred. P. Rush,
William H. Weeks.

On Excursions.

J. E. Simpson,
Erie Locke,
V. T. Malott,
Horace Scott,
D. S. Alvord,
Rob't Connelly,
C. C. Hines.

On Rooms for Meetings.

Valentine Butsch,
John R. Elder,
J. Bernard,
N. McCarty,
James DeSanno.

On Invitations.

Theophilus Parvin,
D. M. Berry,
F. S. Newcomer,
A. Seidensticker,
Thos. D. Kingan.

On Railroads.

Thos. A. Morris,
S. F. Grierson,
David Gibson,
M. M. Landis,
Nathan Kimball.

MEETINGS OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

Meeting.	Date.	Place.	President.	Vice-President.	General Secretary.	Permanent Sec'y.	Treasurer.
1st,	Sept. 20, 1848,	Philadelphia, Pa.,	W. C. Redfield,		Walter R. Johnson,		Jeffries Wyman.
2d,	Aug. 14, 1849,	Cambridge, Mass.,	Joseph Henry,		E. N. Horsford,		A. L. Elwyn.
3d,	March 12, 1850,	Charleston, S. C.,	A. D. Bache,*		L. R. Gibbes,*		St. J. Ravenel.*
4th,	Aug. 19, 1850,	New Haven, Conn.,	A. D. Bache,		E. C. Herrick,		A. L. Elwyn.
5th,	May 5, 1851,	Cincinnati, Ohio,	A. D. Bache,		W. B. Rogers,	S. F. Baird,	A. L. Elwyn,
6th,	Aug. 19, 1851,	Albany, N. Y.,	Louis Agassiz,		W. B. Rogers,	S. F. Baird,	A. L. Elwyn.
7th,	July 28, 1853,	Cleveland, Ohio,	Benj. Peirce,		J. D. Dana,	S. F. Baird,	A. L. Elwyn.
8th,	April 26, 1854,	Washington, D. C.,	J. D. Dana,		J. Lawrence Smith,	Joseph Lovering,	J. L. LeConte.*
9th,	Aug. 15, 1855,	Providence, R. I.,	John Torrey,		Wolcott Gibbs,	Joseph Lovering,	A. L. Elwyn.
10th,	Aug. 20, 1856,	Albany, N. Y.,	James Hall,		B. A. Gould,	Joseph Lovering,	A. L. Elwyn.

* In the absence of the regular officer.

MEETINGS OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

Meeting.	Date.	Place.	President.	Vice-President.	General Secretary.	Permanent Sec'y.	Treasurer.
11th,	Aug. 12, 1857,	Montreal, C. E.,	J. W. Bailey,	Alexis Caswell,	John LeConte,	Joseph Lovering,	A. L. Elwyn.
12th,	April 28, 1858,	Baltimore, Md.,	Alexis Caswell,*	John E. Holbrook,	W. M. Gillespie,	Joseph Lovering,	A. L. Elwyn.
13th,	Aug. 3, 1859,	Springfield, Mass.,	S. Alexander,	Edward Hitchcock,	William Chauvenet,	Joseph Lovering,	A. L. Elwyn.
14th,	Aug. 1, 1860,	Newport, R. I.,	Isaac Lea,	B. A. Gould,	Joseph LeConte,	Joseph Lovering,	A. L. Elwyn.
15th,	Aug. 15, 1866,	Buffalo, N. Y.,	F. A. P. Barnard,	B. A. Gould,	Elias Loomis,	Joseph Lovering,	A. L. Elwyn.
16th,	Aug. 21, 1867,	Burlington, Vt.,	J. S. Newberry,	Wolcott Gibbs,	C. S. Lyman,	Joseph Lovering,	A. L. Elwyn.
17th,	Aug. 5, 1868,	Chicago, Ill.,	B. A. Gould,	Charles Whittlesey,	Simon Newcomb,*	Joseph Lovering,	A. L. Elwyn.
18th,	Aug. 18, 1869,	Salem, Mass.,	J. W. Foster,	O. N. Rood,	O. C. Marsh,	F. W. Putnam,*	A. L. Elwyn.
19th,	Aug. 17, 1870,	Troy, N. Y.,	William Chauvenet	T. S. Hunt, †	C. F. Hartt, ‡	Joseph Lovering,	A. L. Elwyn.

* In the absence of the regular officer.

† The President elect being absent, the Vice-President took his place.

‡ Mr. F. W. Putnam was appointed to fill the place of Mr. Hartt, as he was unable to be present.

CONSTITUTION OF THE ASSOCIATION.*

OBJECTS.

THE Association shall be called THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

The objects of the Association are, by periodical and migratory meetings, to promote intercourse between those who are cultivating science in different parts of the United States, to give a stronger and more general impulse and a more systematic direction to scientific research in our country, and to procure for the labors of scientific men increased facilities and a wider usefulness.

MEMBERS.

RULE 1. Any person may become a member of the Association upon recommendation in writing by two members, nomination by the Standing Committee, and election by a majority of the members present.

OFFICERS.

RULE 2. The officers of the Association shall be a President, Vice-President, General Secretary, Permanent Secretary, and Treasurer. The President, Vice-President, General Secretary, and Treasurer shall be elected at each meeting for the following one; — the three first named officers not to be re-eligible for the next two meetings, and the Treasurer to be re-eligible as long as the Association may desire. The Permanent Secretary shall be elected at each second meeting, and also be re-eligible as long as the Association may desire.

* Adopted August 25, 1856, and ordered to go into effect at the opening of the Montreal Meeting. Amended at Burlington, August, 1867, and at Chicago, August, 1868.

MEETINGS.

Rule 3. The Association shall meet, at such intervals as it may determine, for one week, or longer, — the time and place of each meeting being determined by a vote of the Association at the previous meeting; and the arrangements for it shall be intrusted to the officers and the Local Committee.

STANDING COMMITTEE.

Rule 4. There shall be a Standing Committee, to consist of the President, Vice-President, Secretaries, and Treasurer of the Association, the officers of the preceding year, the permanent Chairman of the Sectional Committees, after these shall have been organized, and six members present from the Association at large, who shall have attended any of the previous meetings, to be elected upon open nomination by ballot on the first assembling of the Association. A majority of the whole number of votes cast, to elect. The General Secretary shall be Secretary of the Standing Committee.

The duties of the Standing Committee shall be, —

1. To assign papers to the respective sections.

2. To arrange the scientific business of the general meetings, to suggest topics, and arrange the programmes for the evening meetings.

3. To suggest to the Association the place and time of the next meeting.

4. To examine, and, if necessary, to exclude papers.

5. To suggest to the Association subjects for scientific reports and researches.

6. To appoint the Local Committee.

7. To have the general direction of publications.

8. To manage any other general business of the Association during the session, and during the interval between it and the next meeting.

9. In conjunction with four from each Section, to be elected by the Sections for the purpose, to make nominations of officers of the Association for the following meeting.

10. To nominate persons for admission to membership.

11. Before adjourning, to decide which papers, discussions, or other proceedings shall be published.

SECTIONS.

RULE 5. The Association shall be divided into two Sections, and as many sub-sections as may be necessary for the scientific business. When not otherwise ordered the sub-sections shall be as follows: SECTION A. — (1) Mathematics and Astronomy; (2) Physics and Chemistry; (3) Microscopy. SECTION B. — (1) Zoölogy and Botany; (2) Geology and Palæontology; (3) Ethnology and Archæology. The two Sections may meet as one.

SECTIONAL OFFICERS AND COMMITTEES.

RULE 6. On the first assembling of the Section, the members shall elect upon open nomination a permanent Chairman and Secretary, also three other members, to constitute, with these officers, a Sectional Committee.

The Section shall appoint, from day to day, a Chairman to preside over its meetings.

RULE 7. It shall be the duty of the Sectional Committee of each Section to arrange and direct the proceedings in their Section; to ascertain what communications are offered; to assign the order in which these communications shall appear, and the amount of time which each shall occupy.

The Sectional Committees may likewise recommend subjects for systematic investigation by members willing to undertake the researches, and to present their results at the next meeting.

The Sectional Committee may likewise recommend reports on particular topics and departments of science, to be drawn up as occasion permits, by competent persons, and presented at subsequent meetings.

REPORTS OF PROCEEDINGS.

RULE 8. Whenever practicable the proceedings shall be reported by professional reporters, or stenographers, whose reports are to be revised by the Secretaries before they appear in print.

PAPERS AND COMMUNICATIONS.

RULE 9. No paper shall be placed in the programme, unless admitted by the Sectional Committee; nor shall any be read, unless an abstract of it has been previously presented to the Secretary of the Section, who shall furnish to the Chairman the titles of papers, of which abstracts have been received.

Rule 10. The author of any paper or communication shall be at liberty to retain his right of property therein, provided he declare such to be his wish before presenting it to the Association.

Rule 11. Copies of all communications, made either to the General Association or to the Sections, must be furnished by the authors; otherwise only the titles, or abstracts, shall appear in the published proceedings.

Rule 12. All papers, either at the general or in the sectional meetings, shall be read, as far as practicable, in the order in which they are entered upon the books of the Association; except that those which may be entered by a member of the Standing Committee of the Association shall be liable to postponement by the proper Sectional Committee.

Rule 13. If any communication be not ready at the assigned time, it shall be dropped to the bottom of the list, and shall not be entitled to take precedence of any subsequent communication.

Rule 14. No exchanges shall be made between members without authority of the respective Sectional Committees.

GENERAL AND EVENING MEETINGS.

Rule 15. The Standing Committee shall appoint any general meeting which the objects and interests of the Association may call for, and the evenings shall, as a rule, be reserved for general meetings of the Association.

These general meetings may, when convened for that purpose, give their attention to any topics of science which would otherwise come before the Sections.

It shall be a part of the business of these general meetings to receive the Address of the President of the last meeting; to hear such reports on scientific subjects as, from their general importance and interests, the Standing Committee shall select; also, to receive from the Chairman of the Sections abstracts of the proceedings of their respective Sections; and to listen to communications and lectures explanatory of new and important discoveries and researches in science, and new inventions and processes in the arts.

ORDER OF PROCEEDINGS IN ORGANIZING A MEETING.

Rule 16. The Association shall be called to order by the President of the preceding meeting; and this officer having resigned the chair to the President elect, the General Secretary shall then report the number of papers relating to each department which have been registered, and the Association consider the most eligible distribution into Sections, when it shall proceed to the election of the additional members of the Standing Committee in the manner before described; the meeting shall then adjourn, and the Standing Committee, having divided the Association into Sections as directed, shall allot to each its place of meeting for the Session. The Sections shall then organize by electing their officers and their representatives in the Nominating Committee, and shall proceed to business.

PERMANENT SECRETARY.

Rule 17. It shall be the duty of the Permanent Secretary to notify members who are in arrears, to provide the necessary stationery and suitable books for the list of members and titles of papers, minutes of the general and sectional meetings, and for other purposes indicated in the rules, and to execute such other duties as may be directed by the Standing Committee or by the Association.

The Permanent Secretary shall make a report annually to the Standing Committee, at its first meeting, to be laid before the Association, of the business of which he has had charge since its last meeting.

All members are particularly desired to forward to the Permanent Secretary, so as to be received before the day appointed for the Association to convene, complete titles of all the papers which they expect to present during its meeting, with an estimate of the time required for reading each, and such abstracts of their contents as may give a general idea of their nature.

Whenever the Permanent Secretary notices any error of fact or unnecessary repetition, or any other important defect in the papers communicated for publication in the proceedings of the Association, he is authorized to commit the same to the author, or to the proper sub-committee of the Standing Committee for correction.

LOCAL COMMITTEE.

RULE 18. The Local Committee shall be appointed from among members residing at, or near, the place of meeting for the ensuing year; and it shall be the duty of the Local Committee, assisted by the officers, to make arrangements and the necessary announcements for the meeting.

The Secretary of the Local Committee shall issue a circular in regard to the time and place of meetings, and other particulars, at least one month before each meeting.

SUBSCRIPTIONS.

RULE 19. The amount of the subscription, at each meeting, of each member of the Association, shall be two dollars, and one dollar in addition shall entitle him to a copy of the proceedings of the annual meeting. These subscriptions shall be received by the Permanent Secretary, who shall pay them over, after the meeting, to the Treasurer.

The admission fee of new members shall be five dollars, in addition to the annual subscription; and no person shall be considered a member of the Association until this admission fee and the subscription for the meeting at which he is elected have been paid.

RULE 20. The names of all persons two years in arrears for annual dues shall be erased from the list of members; provided that two notices of indebtedness, at an interval of at least three months, shall have been previously given.

ACCOUNTS.

RULE 21. The accounts of the Association shall be audited, annually, by auditors appointed at each meeting.

ALTERATIONS OF THE CONSTITUTION.

RULE 22. No article of this Constitution shall be altered, or amended, or set aside, without the concurrence of three-fourths of the members present, and unless notice of the proposed change shall have been given at the preceding annual meeting.*

* See page xxii.

RESOLUTIONS

OF A PERMANENT AND PROSPECTIVE CHARACTER, ADOPTED AUGUST 19, 1857.

1. No appointment may be made in behalf of the Association, and no invitation given or accepted, except by vote of the Association or its Standing Committee.

2. The General Secretary shall transmit to the Permanent Secretary for the files, within two weeks after the adjournment of every meeting, a record of the proceedings of the Association and the votes of the Standing Committee. He shall also, daily, during the meetings, provide the Chairman of the two Sectional Committees with lists of the papers assigned to their Sections by the Standing Committee.

3. All printing for the Association shall be superintended by the Permanent Secretary, who is authorized to employ a clerk for that especial purpose.

4. The Permanent Secretary is authorized to put the proceedings of the meeting to press one month after the adjournment of the Association. Papers which have not been received at that time may be published only by title. No notice of articles not approved shall be taken in the published proceedings.

5. The Permanent Chairman of the Sections are to be considered their organs of communication with the Standing Committee.

6. It shall be the duty of the Secretaries of the two Sections to receive copies of the papers read in their Sections, all sub-sections included, and to furnish them to the Permanent Secretary at the close of the meeting.

7. The Sectional Committees shall meet not later than 9 A.M. daily, during the meetings of the Association, to arrange the programmes of their respective Sections, including all sub-sections,

for the following day. No paper shall be placed upon these programmes which shall not have been assigned to the Section by the Standing Committee. The programmes are to be furnished to the Permanent Secretary not later than 11 A.M.

8. During the meetings of the Association, the Standing Committee shall meet daily, Sundays excepted, at 9 A.M., and the Sections be called to order at 10 A.M., unless otherwise ordered. The Standing Committee shall also meet on the evening preceding the first assembling of the Association at each annual meeting, to arrange for the business of the first day; and on this occasion three shall form a quorum.

9. Associate members may be admitted for one, two, or three years as they shall choose at the time of admission, — to be elected in the same way as permanent members, and to pay the same dues. They shall have all the social and scientific privileges of members, without taking part in the business.

10. No member may take part in the organization and business arrangement of both the Sections.

It has been proposed to change Rule (8) of the Constitution so as to read: —

The Association shall meet, at such intervals as it may determine, for one week, or longer; and the arrangements for it shall be intrusted to the officers and the Local Committee. The Standing Committee shall have power to determine the time and place of each meeting, and shall give due notice of it to the Association.

MEMBERS

OF THE

AMERICAN ASSOCIATION

FOR THE

ADVANCEMENT OF SCIENCE.

A.

Abbe, Cleveland, Cincinnati, Ohio (16).
*Adams, C. B., Amherst, Massachusetts (1).
Adams, Edwin F., Charlestown, Massachusetts (18).
Agassiz, Louis, Cambridge, Massachusetts (1).
Aiken, W. E. A., Baltimore, Maryland (12).
Albert, Augustus J., Baltimore, Maryland (12).
Alexander, Stephen, Princeton, New Jersey (1).
Allen, Zachariah, Providence, Rhode Island (1).
Alvord, Benjamin, Omaha, Nebraska (17).
*Ames, M. P., Springfield, Massachusetts (1).
Andrews, Ebenezer, Chicago, Illinois (17).
Andrews, Edmund, Chicago, Illinois (17).
Andrews, E. B., Marietta, Ohio (7).
Andrews, Joseph H., Chicago, Illinois (17).
*Appleton, Nathan, Boston, Massachusetts (1).
Atwater, Elizabeth E., Chicago, Illinois (17).
Atwater, Samuel T., Chicago, Illinois (17).
Austin, E. P., Cambridge, Massachusetts (18).

B.

Babcock, Henry H., Chicago, Illinois (17).
*Bache, Alexander D., Washington, District of Columbia (1).
Bacon, John, Jr., Boston, Massachusetts (1).
*Bailey, J. W., West Point, New York (1).
Bailey, Loring W., Frederickton, New Brunswick (18).
Baird, Lyman, Chicago, Illinois (17).
Baird, S. F., Washington, District of Columbia (1).

NOTE.—Names of deceased members are marked with an asterisk [*]. The figure at the end of each name refers to the meeting at which the election took place.

Bannister, Henry M., Washington, District of Columbia (17).
Bardwell, F. W., Jacksonville, Florida (13).
Barker, G. F., New Haven, Connecticut (13).
Barnard, F. A. P., New York, New York (7).
Barnard, J. G., New York, New York (14).
Basnett, Thomas, Ottawa, Illinois (8).
Batchelder, J. M., Cambridge, Massachusetts (8).
Beaty, John F., Chicago, Illinois (17).
*Beck, C. F., Philadelphia, Pennsylvania (1).
*Beck, Lewis C., New Brunswick, New Jersey (1).
*Beck, T. Romeyn, Albany, New York (1).
Beebe, G. D., Chicago, Illinois (17).
*Bell, Samuel N., Manchester, New Hampshire (7).
Bickmore, Albert S., New York, New York (17).
Bicknall, Edwin, Cambridge, Massachusetts (18).
Bill, Charles, Springfield, Massachusetts (17).
*Binney, Amos, Boston, Massachusetts (1).
*Binney, John, Boston, Massachusetts (3).
Blake, Eli W., Ithaca, New York (15).
Blake, Eli W., New Haven, Connecticut (1).
Blake, W. P., San Francisco, California (2).
*Blanding, William, Rhode Island (1).
Blaney, J. Van Zandt, Chicago, Illinois (12).
Blatchford, Eliphalet W., Chicago, Illinois (17).
Bolles, E. C., Brooklyn, New York (17).
Bolton, H. C., New York, New York (17).
*Bomford, George, Washington, District of Columbia (1).
Bouvé, Thomas T., Boston, Massachusetts (1).
Bowditch, Henry I., Boston, Massachusetts (2).
Bowen, Chauncey W., Chicago, Illinois (17).
Bradley, Francis, Chicago, Illinois (17).
Bradley, L., Jersey City, New Jersey (15).
Brevoort, J. Carson, Brooklyn, New York (1).
Briggs, A. D., Springfield, Massachusetts (13).
Briggs, D. H., Norton, Massachusetts (18).
Briggs, S. A., Chicago, Illinois (17).
Bross, William, Chicago, Illinois (7).
Brown, Robert, Jr., Cincinnati, Ohio (11).
Brush, George J., New Haven, Connecticut (11).
Bryan, Oliver N., Marshall Hall P. O., Maryland (18).
Bryan, Thomas B., Chicago, Illinois (17).
Buchanan, Robert, Cincinnati, Ohio (2).
Burbank, L. S., Lowell, Massachusetts (18).
*Burnap, G. W., Baltimore, Maryland (12).
*Burnett, Waldo I., Boston, Massachusetts (1).
Burroughs, J. C., Chicago, Illinois (17).
Bushee, James, Worcester, Massachusetts (9).
Butler, Thomas B., Norwalk, Connecticut (10).

C.

Calhoun, John B., Chicago, Illinois (17).
Canby, William M., Wilmington, Delaware (17).
*Carpenter, Thornton, Camden, South Carolina (7).
*Carpenter, William M., New Orleans, Louisiana (1).
Carter, Asher, Chicago, Illinois (17).
Case, Leonard, Cleveland, Ohio (15).
Case, L. B., Richmond, Indiana (17).
*Case, William, Cleveland, Ohio (6).
Caswell, Alexis, Providence, Rhode Island (2).
Cattell, William C., Easton, Pennsylvania (15).
Chadbourn, P. A., Madison, Wisconsin (10).
Chanute, O., Kansas City, Kansas (17).
Chapman, F. M., Chicago, Illinois (17).
*Chapman, N., Philadelphia, Pennsylvania (1).
Chase, George I., Providence, Rhode Island (1).
*Chase, S., Dartmouth, New Hampshire (2).
*Chauvenet, William, St. Louis, Missouri (1).
Chesbrough, E. S., Chicago, Illinois (2).
*Clapp, Asahel, New Albany, Indiana (1).
Clark, John E., Yellow Springs, Ohio (17).
*Clark, Joseph, Cincinnati, Ohio (5).
Clarke, F. W., Boston, Massachusetts (18).
*Cleveland, A. B., Cambridge, Massachusetts (2).
Cochran, D. H., Brooklyn, New York (15).
Coffin, James H., Easton, Pennsylvania (1).
Coffin, John H. C., Washington, District of Columbia (1).
Colbert, E., Chicago, Illinois (17).
*Cole, Thomas, Salem, Massachusetts (1).
*Coleman, Henry, Boston, Massachusetts (1).
Conkling, Frederick A., New York, New York (11).
Cooke, C., Salem, Massachusetts (18).
Cope, Edward D., Philadelphia, Pennsylvania (17).
Copes, Joseph S., New Orleans, Louisiana (11).
Corning, Erastus, Albany, New York (6).
Cramp, J. M., Wolfville, Nova Scotia (11).
Crosby, Alpheus, Salem, Massachusetts (10).
Culver, Howard Z., Chicago, Illinois (17).
Cummings, Joseph, Middletown, Connecticut (13).
Curtis, Josiah, Boston, Massachusetts (18).
Cutting, Hiram A., Lunenburg, Vermont (17).

D.

Dall, William H., Washington, District of Columbia (18).
Dalrymple, E. A., Baltimore, Maryland (11).
Dana, James D., New Haven, Connecticut (1).
Danforth, Edward, Troy, New York (11).
Davis, James, Boston, Massachusetts (1).

Davis, N. S., Chicago, Illinois (17).
Dawson, J. W., Montreal, Canada (10).
*Dean, Amos, Albany, New York (6).
Dean, George W., Fall River, Massachusetts (15).
*Dearborn, George H. A. S., Roxbury, Massachusetts (1).
*Dekay, James E., New York, New York (1).
Delano, B. L., Boston, Massachusetts (16).
Delano, Joseph C., New Bedford, Massachusetts (5).
De Laski, John, Vinalhaven, Maine (18).
*Dewey, Chester, Rochester, New York (1).
Dexter, G. M., Boston, Massachusetts (11).
Dinwiddie, Robert, New York, New York (1).
Dixwell, Epes S., Cambridge, Massachusetts (1).
Doggett, Kate N., Chicago, Illinois (17).
Doggett, William E., Chicago, Illinois (17).
Dorr, E. P., Buffalo, New York (15).
Drowne, Charles, Troy, New York (6).
*Ducatel, J. T., Baltimore, Maryland (1).
*Dumont, A. H., Newport, Rhode Island (14).
*Duncan, Lucius C., New Orleans, Louisiana (10).
Duncan, T. C., Chicago, Illinois (17).
*Dunn, R. P., Providence, Rhode Island (14).
Dyer, Elisha, Providence, Rhode Island (9).

E.

Easton, Norman, Fall River, Massachusetts (14).
Eaton, Daniel C., New Haven, Connecticut (13).
Eaton, James H., Beloit, Wisconsin (17).
Edwards, A. M., New York, New York (18).
Edwards, J. B., Montreal, Canada (17).
Eimbeck, William, St. Louis, Missouri (17).
Eliot, Charles W., Cambridge, Massachusetts (14).
Elliott, Ezekiel B., Washington, District of Columbia (10).
Elwyn, Alfred L., Philadelphia, Pennsylvania (1).
Emerson, George B., Boston, Massachusetts (1).
Emerton, James H., Salem, Massachusetts (18).
Englemann, George, St. Louis, Missouri (1).
Engstrom, A. B., Burlington, New Jersey (1).
Eustis, Henry L., Cambridge, Massachusetts (2).
*Everett, Edward, Boston, Massachusetts (2).
Ewing, Thomas, Lancaster, Ohio (5).

F.

Fairbanks, Henry, Hanover, New Hampshire (14).
Farmer, Moses G., Salem, Massachusetts (9).
Farnham, Thomas, Buffalo, New York (15).
Farrar, Henry W., Chicago, Illinois (17).
Fellowes, R. S., New Haven, Connnecticut (18).

Fenton, William, Troy, New York (18).
Ferrell, William, Cambridge, Massachusetts (11).
Ferris, Isaac, New York, New York (6).
Feuchtwanger, Louis, New York, New York (11).
Fisher, Davenport, Milwaukie, Wisconsin (17).
Fisher, Mark, Trenton, New Jersey (10).
*Fitch, Alexander, Hartford, Connecticut (1).
Fitch, Edward H., Ashtabula, Ohio (11).
Fitch, O. H., Ashtabula, Ohio (7).
*Forbush, E. B., Buffalo, New York (15).
Foster, Henry, Clifton, New York (17).
Foster, John, Schenectady, New York (17).
Foster, J. W., Chicago, Illinois (1).
*Fox, Charles, Grosse Isle, Michigan (7).
Frothingham, Frederick, Buffalo, New York (11).

G.

Gavit, John E., New York, New York (1).
*Gay, Martin, Boston, Massachusetts (1).
*Gibbon, J. H., Charlotte, North Carolina (3).
Gill, Theodore, Washington, District of Columbia (17).
*Gillespie, W. M., Schenectady, New York (10).
Gilman, Daniel C., New Haven, Connecticut (10).
*Gilmor, Robert, Baltimore, Maryland (1).
Goessman, C. A., Amherst, Massachusetts (18).
Gold, Theodore S., West Cornwall, Connecticut (4).
*Gould, Augustus A., Boston, Massachusetts (11).
*Gould, B. A., Boston, Massachusetts (2).
Gould, B. A., Cambridge, Massachusetts (2).
*Graham, James D., Washington, District of Columbia (1).
Gray, Asa, Cambridge, Massachusetts (1).
*Gray, James H., Springfield, Massachusetts (6).
Greeley, Samuel S., Chicago, Illinois (17).
Green, Traill, Easton, Pennsylvania (1).
*Greene, Benjamin D., Boston, Massachusetts (1).
Greene, Dascom, Troy, New York (17).
Greene, Francis C., Easthampton, Massachusetts (11).
Gregory, J. J. H., Marblehead, Massachusetts (18).
*Griffith, Robert E., Philadelphia, Pennsylvania (1).
Grimes, J. S., New York, New York (17).
Grinnan, A. G., Orange Court House, Virginia (7).
Grover, Z., Chicago, Illinois (17).
Guyot, Arnold, Princeton, New Jersey (1).

H.

*Hackley, Charles W., New York, New York (4).
Hadley, George, Buffalo, New York (6).
Hagen, Hermann A., Cambridge, Massachusetts (17).

Haldeman, S. S., Columbia, Pennsylvania (1).
Hale, Edwin M., Chicago, Illinois (17).
*Hale, Enoch, Boston, Massachusetts (1).
Hall, James, Albany, New York (1).
Hall, L. B., Hanover, New Hampshire (18).
Hall, N. K., Buffalo, New York (7).
Hambly, J. B., Portsmouth, Rhode Island (18).
Hamel, Thomas, Quebec, Canada (18).
Hamlin, A. C., Bangor, Maine (10).
Hance, Ebenezer, Morrisville, Pennsylvania (7).
Hanover, M. D., Cincinnati, Ohio (13).
*Hare, Robert, Philadelphia, Pennsylvania (11).
*Harlan, Joseph G., Haverford, Pennsylvania (8).
*Harlan, Richard, Philadelphia, Pennsylvania (1).
Harris, A. A., Cambridge, Massachusetts (17).
Harris, James W., Cambridge, Massachusetts (17).
*Harris, Thaddeus W., Cambridge, Massachusetts (1).
Harrison, B. F., Wallingford, Connecticut (11).
*Hart, Simeon, Farmington, Connecticut (1).
Hartshorne, Henry, Philadelphia, Pennsylvania (12).
Haven, Joseph, Chicago, Illinois (17).
Hawkins, B. W., New York, New York (17).
*Hayden, H. H., Baltimore, Maryland (1).
Hayes, George E., Buffalo, New York (15).
*Hayward, James, Boston, Massachusetts (1).
Henry, Joseph, Washington, District of Columbia (1).
Herzer, W., Columbus, Ohio (15).
Hickcox, S. V. R., Chicago, Illinois (17).
Hilgard, Eugene W., Oxford, Mississippi (11).
Hilgard, Julius E., Washington, District of Columbia (4).
Hilgard, Theodore C., St. Louis, Missouri (17).
Hill, S. W., Hancock, Lake Superior (6).
Hill, Thomas, Waltham, Massachusetts (3).
Hinrichs, Gustavus, Iowa City, Iowa (17).
Hitchcock, Charles H., Hanover, New Hampshire (11).
*Hitchcock, Edward, Amherst, Massachusetts (1).
Hitchcock, Edward, Amherst, Massachusetts (4).
Hitt, Isaac R., Chicago, Illinois (17).
Hoadley, E. S., Springfield, Massachusetts (13).
Holbrook, J. E., Charleston, South Carolina (1).
Holmes, E. L., Chicago, Illinois (17).
Homes, Henry A., Albany, New York (11).
Horsford, E. N., Cambridge, Massachusetts (1).
*Horton, William, Craigville, New York (1).
Hough, Franklin B., Lowville, New York (4).
Hough, G. W., Albany, New York (15).
*Houghton, Douglas, Detroit, Michigan (1).
Howell, Robert, Nichols, New York (6).
Hoy, Philo R., Racine, Wisconsin (17).
Hubbard, Gurdon S., Chicago, Illinois (17).

Hubbard, Oliver P., New Haven, Connecticut (1).
Hubbard, Sara A., Kalamazoo, Michigan (17).
*Hubbert, James, Richmond, Province of Quebec (16).
Humphrey, D., Lawrence, Massachusetts (18).
Hunt, Charles S., New York, New York (17).
*Hunt, E. B., Washington, District of Columbia (2).
*Hunt, Freeman, New York, New York (11).
Hunt, George, Providence, Rhode Island (9).
Hunt, T. Sterry, Montreal, Canada (1).
Hyatt, Alpheus, Salem, Massachusetts (18).
Hyatt, James, Bangall, New York (10).

I.

*Ives, Thomas P., Providence, Rhode Island (10).

J.

Jenks, J. W. P., Middleboro', Massachusetts (2).
Jillson, B. C., Nashville, Tennessee (14).
*Johnson, W. R., Washington, District of Columbia (1).
Johnston, John, Middletown, Connecticut (1).
*Jones, Catesby A. R., Washington, District of Columbia (8).
Joy, C. A., New York, New York (8).
Judd, Orange, New York, New York (4).

K.

Kedzie, J. H., Chicago, Illinois (17).
Keely, G. W., Waterville, Maine (1).
Keep, N. C., Boston, Massachusetts (13).
Kerr, W. C., Raleigh, North Carolina (10).
Kimball, J. P., New York, New York (15).
King, Mary B. A., Rochester, New York (15).
Kirkpatrick, James A., Philadelphia, Pennsylvania (7).
Kirkwood, Daniel, Bloomington, Indiana (7).
Klippart, John H., Columbus, Ohio (17).
Knickerbocker, Charles, Chicago, Illinois (17).

L.

Lambert, Thomas R., Charlestown, Massachusetts (18).
Lapham, Increase A., Milwaukie, Wisconsin (3).
*Lasel, Edward, Williamstown, Massachusetts (1).
Lattimore, S. A., Rochester, New York (15).
Lawrence, Edward, Charlestown, Massachusetts (18).
Lawrence, George N., New York, New York (7).
Lea, Isaac, Philadelphia, Pennsylvania (1).
Leakin, George A., Baltimore, Maryland (17).
*Lederer, Baron von, Washington, District of Columbia (1).
Lesley, Joseph, Jr., Philadelphia, Pennsylvania (8).

*Lesley, J. P., Philadelphia, Pennsylvania (2).
*Lieber, Oscar M., Columbia, South Carolina (8).
*Lincklaen, Ledyard, Cazenovia, New York (1).
Lincoln, Robert T., Chicago, Illinois (17).
Lindsley, J. B., Nashville, Tennessee (1).
*Linsley, James H., Stafford, Connecticut (1).
Little, George, Oxford, Mississippi (15).
Locke, Luther F., Nashua, New Hampshire (7).
Logan, William E., Montreal, Canada (1).
Lombard, Benjamin, Chicago, Illinois (17).
Loomis, Elias, New Haven, Connecticut (1).
*Loosey, Charles F., New York, New York (12).
*Lothrop, Joshua R., Buffalo, New York (15).
Lovering, Joseph, Cambridge, Massachusetts (2).
Lupton, N. T., Greensboro, Alabama (17).
Lyman, B. S., Philadelphia, Pennsylvania (15).
Lyman, Chester S., New Haven, Connecticut (14).
Lyman, Henry M., Chicago, Illinois (17).

M.

Maack, G. A., Cambridge, Massachusetts (18).
McCagg, Ezra B., Chicago, Illinois (17).
*M'Conihe, Isaac, Troy, New York (4).
McCoy, Amasa, Chicago, Illinois (17).
McMurtrie, Horace, Boston, Massachusetts (17).
McNeil, J. A., Grand Rapids, Michigan (18).
McRae, John, Camden, South Carolina (3).
Marcy, Oliver, Evanston, Illinois (10).
*Marsh, Dexter, Greenfield, Massachusetts (1).
Marsh, H. H., Chicago, Illinois (17).
Marsh, O. C., New Haven, Connecticut (15).
Marshall, Orasmus H., Buffalo, New York (15).
*Mather, William W., Columbus, Ohio (1).
Mauran, J., Providence, Rhode Island (2).
Mayhew, D. P., Ypsilanti, Michigan (13).
Maynard, Alleyne, Cleveland, Ohio (7).
·Maynard, George W., Troy, New York (10).
Meade, George G., Philadelphia, Pennsylvania (15).
Means, A., Oxford, Georgia (5).
Meehan, Thomas, Germantown, Pennsylvania (17).
Meek, F. B., Washington, District of Columbia (6).
Meigs, James A., Philadelphia, Pennsylvania (12).
Miles, Henry H., Quebec, Canada East (11).
Minifie, William, Baltimore, Maryland (12).
Mitchell, Maria, Poughkeepsie, New York (4).
Mitchell, William H., Florence, Alabama (17).
Morgan, Lewis H., Rochester, New York (10).
Morison, N. H., Baltimore, Maryland (17).
Morley, Edward W., Pittsfield, Massachusetts (18).

Morris, John G., Baltimore, Maryland (12).
Morse, Edward S., Salem, Massachusetts (18).
Morton, Henry, Hoboken, New Jersey (18).
*Morton, S. G., Philadelphia, Pennsylvania (1).
Murray, David, New Brunswick, New Jersey (11).

N.

Nason, Henry B., Troy, New York (13).
Nelson, Cleland K., Annapolis, Maryland (12).
Newberry, J. S., New York, New York (5).
Newcomb, Simon, Washington, District of Columbia (18).
*Newton, E. H., Cambridge, New York (1).
Newton, Hubert A., New Haven, Connecticut (6).
Newton, John, Pensacola, Florida (7).
Nichols, Charles A., Providence, Rhode Island (17).
Nichols, William R., Boston, Massachusetts (18).
*Nicollett, J. N., Washington, District of Columbia (1).
Niles, W. H., Cambridge, Massachusetts (16).
*Norton, J. P., New Haven, Connecticut (1).
Norton, W. A., New Haven, Connecticut (6).

O.

*Oakes, William, Ipswich, Massachusetts (1).
Ogden, Mahlon D., Chicago, Illinois (17).
Ogden, W. B., Chicago, Illinois (17).
Oliver, James Edward, New York, New York (7).
*Olmsted, Alexander F., New Haven, Connecticut (4).
*Olmsted, Denison, New Haven, Connecticut (1).
*Olmsted, Denison, Jr., New Haven, Connecticut (1).
Ordway, John M., Boston, Massachusetts (9).
Orton, James, Poughkeepsie, New York (18).
Osten, Sacken, Baron R. von, New York, New York (10).

P.

Packard, A. S., Jr., Salem, Massachusetts (16).
Page, Peter, Chicago, Illinois (17).
Paine, Cyrus F., Rochester, New York (12).
Paine, Nathaniel, Worcester, Massachusetts (18).
Painter, Minshall, Lima, Pennsylvania (7).
*Parkman, Samuel, Boston, Massachusetts (1).
Parmelee, Dubois D., New York, New York (15).
Parry, Charles C., Washington, District of Columbia (6).
Peabody, S. H., Chicago, Illinois (17).
Peirce, Benjamin, Cambridge, Massachusetts (1).
Peirce, B. O., Beverly, Massachusetts (18).
Perkins, George H., Burlington, Vermont (17).
Perkins, George R., Utica, New York (7).
Perkins, Maurice, Schenectady, New York (15).

Perry, John B., Cambridge, Massachusetts (16).
*Perry, M. C., New York, New York (10).
Phelps, Almira L., Baltimore, Maryland (13).
Phelps, Charles E., Baltimore, Maryland (13).
Phippen, George D., Salem, Massachusetts (18).
Pickering, Edward C., Boston, Massachusetts (18).
*Plumb, Ovid, Salisbury, Connecticut (9).
Pope, Charles A., St. Louis, Missouri (12).
*Porter, John A., New Haven, Connecticut (14).
Pourtales, L. F., Washington, District of Columbia (1).
Powell, Edwin, Chicago, Illinois (17).
Pratt, William H., Davenport, Iowa (17).
Prescott, William, Concord, New Hampshire (1).
Pruyn, J. V. L., Albany, New York (1).
*Pugh, Evan, Centre Co., Pennsylvania (14).
Pumpelly, Raphael, Cambridge, Massachusetts (17).
Putnam, F. W., Salem, Massachusetts (10).

Q.

Quincy, Edmund, Jr., Boston, Massachusetts (11).

R.

Rauch, J. H., Chicago, Illinois (11).
Raymond, R. W., New York, New York (15).
Read, Daniel, Columbia, Missouri (17.
Redfield, John H., Philadelphia, Pennsylvania (1).
*Redfield, William C., New York, New York (1).
Rice, William N., Middletown, Connecticut (18).
Riley, Charles V., St. Louis, Missouri (17).
Ritchie, E. S., Boston, Massachusetts (10).
Robertson, Thomas D., Rockford, Illinois (10).
Rochester, Thomas F., Buffalo, New York (15).
Rockwell, Alfred P., New Haven, Connecticut (10).
Rockwell, John, La Salle, Illinois (11).
*Rockwell, John A., Norwich, Connecticut (10).
Rockwell, Joseph P., Boston, Massachusetts (17).
Rogers, Fairman, Philadelphia, Pennsylvania (11).
*Rogers, James B., Philadelphia, Pennsylvania (1).
Rogers, W. A., Alfred Centre, New York (15).
Rogers, W. B., Boston, Massachusetts (1).
Rood, O. N., New York, New York (14).
Roosevelt, Clinton, New York, New York (11).
Root, Edward W., Clinton, New York (17).
Rumsey, Bronson C., Buffalo, New York (15).
Rumsey, George T., Chicago, Illinois (17).
Runkle, J. D., Boston, Massachusetts (2).
Rutherford, Louis M., New York, New York (13).
Ryerson, Joseph T., Chicago, Illinois (17).

S.

Safford, J. M., Nashville, Tennessee (6).
Safford, Truman H., Chicago, Illinois (13).
Samson, George W., Washington, District of Columbia (18).
Sanborn, Francis G., Boston, Massachusetts (13).
Scammon, J. Young, Chicago, Illinois (17).
Schanck, J. Stillwell, Princeton, New Jersey (4).
Schott, Charles A., Washington, District of Columbia (8).
Scudder, Samuel H., Cambridge, Massachusetts (13).
Seely, Charles A., New York, New York (18).
Seward, William H., Auburn, New York (1).
Sheafer, P. W., Pottsville, Pennsylvania (4).
Sheldon, Edwin H., Chicago, Illinois (17).
Sias, Solomon, Charlotteville, New York (10).
Sill, Elisha N., Cuyahoga Falls, Ohio (6).
*Silliman, Benjamin, New Haven, Connecticut (1).
Silliman, Benjamin, New Haven, Connecticut (1).
Smith, A. D., Providence, Rhode Island (14).
Smith, J. L., St. Louis, Missouri (14).
*Smith, J. V., Cincinnati, Ohio (5).
Smith, James Y., Providence, Rhode Island (9).
*Smith, Lyndon A., Newark, New Jersey (9).
Snell, Eben S., Amherst, Massachusetts (2).
*Sparks, Jared, Cambridge, Massachusetts (2).
Spencer, Charles A., Brooklyn, New York (14).
Sprague, Albert A., Chicago, Illinois (17).
Spring, Charles H., Boston, Massachusetts (13).
Stanard, Benjamin A., Cleveland, Ohio (6).
Stearns, Josiah A., Boston, Massachusetts (10).
Stearns, R. E. C., San Francisco, California (18).
Steiner, Lewis H., Frederick City, Maryland (7).
Stephens, W. H., Lowville, New York (18).
Stimpson, Frederick E., Boston, Massachusetts (18).
Stimpson, William, Chicago, Illinois (12).
Stockwell, John N., Brecksville, Ohio (18).
Stoddard, O. N., Oxford, Ohio (7).
Stone, Samuel, Chicago, Illinois (17).
Storer, D. H., Boston, Massachusetts (1).
Storer, Frank H., Boston, Massachusetts (13).
Stoughton, T. M., Factory Village, Massachusetts (18).
Sullivant, W. S., Columbus, Ohio (7).
Swallow, G. C., Columbia, Missouri (10).
Swasey, Oscar F., Beverly, Massachusetts (17).

T.

*Tallmadge, James, New York, New York (1).
*Taylor, Richard C., Philadelphia, Pennsylvania (1).
Tenney, Sanborn, Williamstown, Massachusetts (17).

*Teschemacher, J. E., Boston, Massachusetts (1).
Thompson, Aaron R., New York, New York (1).
Thompson, Harvey M., Chicago, Illinois (17).
*Thompson, Z., Burlington, Vermont (1).
*Thurber, Isaac, Providence, Rhode Island (9).
Tillman, S. D., Jersey City, New Jersey (15).
Tingley, Jeremiah, Meadville, Pennsylvania (15).
Tingley, Joseph, Greencastle, Indiana (14).
Tolles, Robert B., Boston, Massachusetts (15).
Torrey, John, New York, New York (1).
*Totten, J. G., Washington, District of Columbia (1).
Townsend, Franklin, Albany, New York (4).
*Townsend, John K., Philadelphia, Pennsylvania (1).
Townshend, N. S., Avon, Ohio (17).
Tracy, John F., Chicago, Illinois (17).
Trembly, J. B., Toledo, Ohio (17).
*Troost, Gerard, Nashville, Tennessee (1).
Trowbridge, W. P., New Haven, Connecticut (10).
True, Nathaniel T., Bethel, Maine (17).
*Tuomey, M., Tuscaloosa, Alabama (1).
Turner, R. S., Reading, Pennsylvania (18).
Tuttle, Albert H., Cleveland, Ohio (17).
Twining, A. C., New Haven, Connecticut (18).
*Tyler, Edward R., New Haven, Connecticut (1).
Tyson, Philip T., Baltimore, Maryland (12).

U.

Upham, J. Baxter, Boston, Massachusetts (14).
Upton, George P., Chicago, Illinois (17).

V.

Vail, Hugh D., Philadelphia, Pennsylvania (18).
*Vancleve, John W., Dayton, Ohio (1).
Van der Weyde, P. H., New York, New York (17).
*Vanuxem, Lardner, Bristol, Pennsylvania (1).
Vaux, William S., Philadelphia, Pennsylvania (1).
Verrill, A. E., New Haven, Connecticut (16).
Vose, George L., Minneapolis, Minnesota (15).

W.

Waddell, John N., Oxford, Mississippi (17).
*Wadsworth, James S., Genesee, New York (2).
*Wagner, Tobias, Philadelphia, Pennsylvania (9).
Walker, George C., Chicago, Illinois (17).
*Walker, Joseph, Oxford, New York (10).
*Walker, Sears C., Washington, District of Columbia (1).
*Walker, Timothy, Cincinnati, Ohio (4).
Walling, H. F., Easton, Pennsylvania (16).

Wanzer, Ira, Lanesville, Connecticut (18).
Ward, Henry A., Rochester, New York (13).
Ward, R. H., Troy, New York (17).
Warner, James D., Brooklyn, New York (18).
Warren, G. K., Washington, District of Columbia (12).
*Warren, John C., Boston, Massachusetts (1).
Warren, S. E., Troy, New York (17).
Watson, James C., Ann Arbor, Michigan (13).
Watson, William, Cambridge, Massachusetts (12).
Webb, Benjamin, Jr., Salem, Massachusetts (18).
*Webster, H. B., Albany, New York (1).
*Webster, J. W., Cambridge, Massachusetts (1).
*Webster, M. H., Albany, New York (1).
Wells, Daniel H., New Haven, Connecticut (18).
Wenz, J., New Orleans, Louisiana (15).
Wheatland, Henry, Salem, Massachusetts (1).
*Wheatland, Richard H., Salem, Massachusetts (13).
Wheatley, Charles M , Phœnixville, Pennsylvania (1).
Wheeler, T. B., Montreal, Canada (11).
Wheildon, W. W., Charlestown, Massachusetts (13).
Whitfield, R. P., Albany, New York (18).
Whitney, Asa, Philadelphia, Pennsylvania (1).
Whitney, J. D., Cambridge, Massachusetts (1).
Whitney, William D., New Haven, Connecticut (12).
Whittlesey, Charles, Cleveland, Ohio (1).
*Willard, Emma, Troy, New York (15).
Williams, Henry W., Boston, Massachusetts (11).
Williamson, R. S., San Francisco, California (12).
Wilson, Charles L., Chicago, Illinois (17).
Winchell, Alexander, Ann Arbor, Michigan (3).
Winslow, Ferdinand S., Chicago, Illinois (17).
*Woodbury, L., Portsmouth, New Hampshire (1).
Woodworth, John M., Chicago, Illinois (17).
Worthen, A. H., Springfield, Illinois (5).
Wright, A. W., Williamstown, Massachusetts (14).
*Wright, John, Troy, New York (1).
Wurtele, Louis C., Acton Vale, Canada East (11).
Wurtz, Henry, New York, New York (10).
Wyman, Jeffries, Cambridge, Massachusetts (1).

Y.

Youmans, E. L., New York, New York (6).
Young, Charles A., Hanover, New Hampshire (18).
*Young, Ira, Hanover, New Hampshire (7).

This list contains five hundred and fifty-six names, of which one hundred and twenty-two are of deceased members. The names of those who were chosen at Troy, and who have already joined the Association, have not yet been incorporated into the general catalogue of members, but are printed separately.

MEMBERS

WHO JOINED AT

THE SALEM MEETING.

Adams, Samuel, Jacksonville, Illinois.
Agassiz, Alexander E. R., Cambridge, Massachusetts.
Allen, J., Alfred Centre, New York.
Allen, Joel A., Cambridge, Massachusetts.
Austin, E. L., Plymouth, Ohio.

Bachelder, J. H., Salem, Massachusetts.
Barnard, James M., Boston, Massachusetts.
Bethune, Charles J. S., Port Hope, Canada.
Bliss, Porter C , New York, New York.
Boynton, John F., Syracuse, New York.

Chase, Pliny E., Philadelphia, Pennsylvania.
Chase, R. Stuart, Haverhill, Massachusetts.
Cogswell, George, Bradford, Massachusetts.
Cogswell, William, Salem, Massachusetts.
Cook, George H., New Brunswick, New Jersey.
Crampton, R. C., Jacksonville, Illinois.
Crosby, Thomas R., Hanover, New Hampshire.
Cummings, John, Woburn, Massachusetts.

Devereux, J. H., Cleveland, Ohio.

Ellenwood, Charles N., San Francisco, California.
Endicott, William C., Salem, Massachusetts.

Foucou, Felix, Madison, Wisconsin.
Frothingham, Richard, Charlestown, Massachusetts.

Gilbert, G. K., Toledo, Ohio.
Goodell, Abner C., Jr., Salem, Massachusetts.

Hagar, D. B., Salem, Massachusetts.
Hartt, Charles F., Ithaca, New York.
Hoyt, J. W., Madison, Wisconsin.

Jasper, G. A., Charlestown, Massachusetts.
Johnson, Amos H., Salem, Massachusetts.

Langley, S. P., Allegheny, Pennsylvania.
Lockwood, Samuel, Freehold, New Jersey.
Loring, George B., Salem, Massachusetts.
Lyon, Henry, Charlestown, Massachusetts.

Mack, David, Belmont, Massachusetts.
Marden, George H., Charlestown, Massachusetts.
Monroe, William, Boston, Massachusetts.

Patton, William W., Chicago, Illinois.
Peckham, S. F., Providence, Rhode Island.
Perkins, Henry C., Newburyport, Massachusetts.

Rogers, Robert E., Philadelphia, Pennsylvania.
Rosseter, G. R., Marietta, Ohio.

Scofield, Samuel L., New York, New York.
Shepard, L. D., Boston, Massachusetts.
Sherwood, Andrew, Mansfield, Pennsylvania.
Smith, Isaac T., New York, New York.
Smith, Rollin A., Fond-du-Lac, Wisconsin.
Smith, Sidney I., New Haven, Connecticut.
Squier, E. G., New York, New York.
Stevens, R. P., New York, New York.
Stimpson, Thomas M., Peabody, Massachusetts.

Utley, Charles H., Buffalo, New York.

Valentine, Benjamin E., Brooklyn, New York.

Walker, Charles A., Chelsea, Massachusetts.
Warren, G. W., Charlestown, Massachusetts.
White, A. D., Ithaca, New York.
Williams, H. S., New Haven, Connecticut.
Woolworth, S. B., Albany, New York.

MEMBERS

WHO JOINED AT

THE TROY MEETING.

Babcock, George, Troy, New York.
Barker, S. W., White Creek, New York.
Beattie, David, Troy, New York.
Benjamin, E. B., New York, New York.
Blaisdell, A. H., Coeymans, New York.
Blatchley, S. L., New Haven, Connecticut.
Bontencou, R. B., Troy, New York.
Boynton, Susan P., Lynn, Massachusetts.
Brackett, C. F., Brunswick, Maine.
Broome, Gordon, Montreal, Canada.
Bush, Stephen, Waterford, New York.
Burden, Henry, Jr., Troy, New York.

Chandler, C. F., New York, New York.
Chandler, William H., New York, New York.
Childs, Walter C., Pittsburg, Pennsylvania.
Cooley, Le Roy C., Albany, New York.
Cox, Edward T., Indianapolis, Indiana.

Dodd, C. M., Williamstown, Massachusetts.
Doughty, John W., Newburgh, New York.

Eaton, D. C., Brooklyn, New York.
Emerson, Benjamin K., Amherst, Massachusetts.
Ennis, Jacob, Philadelphia, Pennsylvania.
Evans, Asher B., Lockport, New York.
Evans, E. W., Ithaca, New York.

Fisher, Clark, Trenton, New Jersey.
Fisk, Richmond, Jr., Canton, New York.
Ford, S. W., Troy, New York.
Forsyth, James, Troy, New York.
Forsyth, Robert, Troy, New York.
Francis, C. S., Troy, New York.

Gale, Frederick W., Troy, New York.
Gillespie, John H., Troy, New York.
Glazier, Sarah M., Hartford, Connecticut.
Gonzales, Juan A., Jr., New York, New York.
Greene, David M., Troy, New York.
Griswold, John A., Troy, New York.

Hagan, W. E., Troy, New York.
Hale, William H., Albany, New York.
Hall, Benjamin H., Troy, New York.
Hall, George E., Cleveland, Ohio.
Hanaman, C. E., Troy, New York.
Harris, E. P., Amherst, Massachusetts.
Hart, William H., Troy, New York.
Hedrick, B. S., Washington, District of Columbia.
Heimstreet, John W., Troy, New York.
Holley, A. L., Troy, New York.
Holley, George W., Troy, New York.
Hopkins, Albert, Williamstown, Massachusetts.
Horribin, William T., Bennington, Vermont.
House, John C., Waterford, New York.
Howe, E. C., New Baltimore, New York.
Huntington, J. H., Hanover, New Hampshire.
Hyatt, Jonathan S., Morrisania, New York.

Kellogg, Giles B., Troy, New York.
Kellogg, Justin, Troy, New York.
Knapp, Frederick N., Plymouth, Massachusetts.

Leckie, Robert G., Actonvale, Quebec.
Lennon, W. H., Brockport, New York.

MacArthur, Charles L., Troy, New York.
McClellan, R. H., Troy, New York.
M'Conihe, Sarah S., Troy, New York.
Mann, Frank N., Troy, New York.
Mayer, Alfred M., South Bethlehem, Pennsylvania.
Merriam, William H., Troy, New York.
Morris, Oran W., New York, New York.

Nickel, George D., Collingsville, Pennsylvania.

O'Donnell, Emma, Lansingburg, New York.
Orton, Edward, Yellow Springs, Ohio.
Osborne, A. O., Waterville, New York.
Osborne, Ada M., Waterville, New York.

Parmenter, Jerome B., Troy, New York.
Peck, W. A., Troy, New York.

Peirce, H. A., Lansingburg, New York.
Putnam, Adelaide M., Salem, Massachusetts.

Reybold, Mary, Delaware City, Delaware.

Sanders, Benjamin D., Wellsburg, West Virginia.
Seymour, Charles J., Binghampton, New York.
Seymour, W. P., Troy, New York.
Shaler, N. S., Cambridge, Massachusetts.
Silliman, Justus M., Easton, Pennsylvania.
Storke, Helen L., Auburn, New York.
Strawbridge, William C., Oxford, Pennsylvania.
Stuart, F. H., Hanover, New Hampshire.

Thompson, Robert H., Troy, New York.
Townsend, Martin I., Troy, New York.
Tracy, C. M., Lynn, Massachusetts.
Treat, Joseph, Vineland, New Jersey.

Uhler, Philip R., Baltimore, Maryland.

Van Horne, W. C., Alton, Illinois.

Walker, J. R., New Orleans, Louisiana.
Warder, Robert B., Champaign, Illinois.
Wells, George A., Troy, New York.
Wendell, August, Troy, New York.
Wheeler, Lewis C., Troy, New York.
Whitney, Mary W., Waltham, Massachusetts.
Wilber, G. M., Pineplains, New York.
Wilder L., Hoosick Falls, New York.
Willard, John H., Troy, New York.
Willard, Sarah L., Troy, New York.
Williams, J. G., Detroit, Michigan.
Winchell, N. H., Ann Arbor, Michigan.

Young, William H., Troy, New York.

ADDRESS

OF

J. W. FOSTER,

EX-PRESIDENT OF THE ASSOCIATION.

Mr. President, and Gentlemen of the American Association for the Advancement of Science:

There is an article contained in our Constitution which requires the retiring President to address the Association in general meeting; and custom has prescribed that he select for his theme some new and important discoveries in science, or some new inventions and processes in the arts.

It is in the discharge of this duty that I appear before you on this occasion, and solicit your attention for the passing hour. So vast is the domain of science, and so numerous have become its cultivators in almost every part of the world, that, even if I had the capacity, the labor of embodying the results of a single year, in a brief address, would be a mere accumulation of details devoid of that spirit which gives them value, — generalization.

I shall, therefore, restrict myself to the researches which have been made in those departments of science which with me have been the subjects of special investigation, and shall seek to set forth what others have accomplished, rather than to advance original views.

It will be found that, throughout all time, since the earth became fitted for the habitation of organic life, there have been great cycles of heat and cold, and that these cycles have exercised a marked influence in the modification of all terrestrial forms. To traverse the whole ground, would employ too much time; and I shall, therefore, restrict myself to the changes which barely antedate the Human Epoch.

We know that the Tertiary Age, so far, at least, as relates to the northern hemisphere, was characterized by a warm and equable

climate, extending even to the Polar Sea. Where now blooms the Andromeda close by banks of perpetual snow, at that time grew a luxuriant forest vegetation. McClure's sledging party gathered fragments of fossil wood, acorns, and fir cones in the interior of Bank's Land, far within the limits of the Arctic Circle. As high as latitude 70° N. in Greenland, large forests lie prostrate and encased in ice. At Disco Island, the northern verge of European settlement, the strata are full of the trunks, branches, leaves, and even the seeds and fruit-cones of trees, comprising firs, sequoias, elms, magnolias, and laurels, — a vegetation characteristic of the Miocene Period of Central Europe. Professor Heer particularly notices the *Sequoia Langsdorfii*, which is very closely allied to the *Sequoia sempervirens* of the Coast Range of California.

Spitzbergen was clothed with a forest vegetation equally luxuriant, amongst which the Swedish naturalists recognize the swamp-cypress (*Taxodium dubium*) in a fossilized state at Bell's Sound (76° N.), and the plantain and linden in King's Bay (78° and 79° N.). The same Sequoia was observed by Sir John Richardson within the Arctic Circle west of Mackenzie River. The lignite beds of Iceland have yielded to the botanists, Steenstrup and Heer, fifteen arborescent forms identical with the Miocene plants of Europe.

In the flora of the Great Lignite Basin of Nebraska, which is referred to the Miocene Age, Hayden has detected the oak, the tulip or poplar, the elm and walnut, and a true fan-palm, with a leaf-spread of twelve feet; — all, however, of extinct species. These forms he regards as characteristic of a sub-tropical climate such as now prevails in the Gulf States. The fan-palm (*Sabal Campbellii*) is the representative of the *Sabal major* of the European Tertiaries, and the *Sabal palmetto* of our Southern States.

The *Cinnamonium*, an unquestioned tropical type, while not thus far detected in the Missouri Basin, has been found by Lesquereaux in the Cretaceous (?) beds of Bellingham Bay, on our North-western coast; in the Eocene of the Lower Mississippi, and in the lignite beds of Vermont.

Professor Newberry, in a review of the flora of the Cretaceous and Tertiary Ages of North America, thus remarks: —

"We have, therefore, negative evidence, though it may be reversed at an early day by further observations, that the climate of the interior of our continent, during the Tertiary Age, was somewhat warmer than during the

Cretaceous Period; and that, during both, the same relative differences of climate prevailed between the western and central portions that exist at the present day."

The Drift Epoch was ushered in by a marked change in physical influences, by which the whole flora of the extreme northern hemisphere was so far affected that certain forms were blotted out of existence, while other forms were forced to seek, by migration, a more congenial climate, and accommodate themselves to altered conditions. In the higher regions we find a predominating growth of mosses and saxifrages, and at the southern limits of the Drift a buried vegetation of an Alpine character.

If we examine the faunæ of the two epochs — particularly the land animals which we may suppose to be peculiarly susceptible to atmospheric changes — we shall find that there was a marked modification of forms. Dr. Leidy, in his late work on the extinct mammalian faunæ of Dakota and Nebraska, states that, of the thirty-two genera of Miocene animals, not one occurs in the Quatenary formation of North America. In comparing the Miocene and Pliocene faunæ with each other, as represented mainly by the remains from the Mauvaises Terres and the Niobrara River, scarcely a genus is common to both. "In view," he continues, "of the consecutive order and close approximation of position of the two formations and faunæ, such exclusiveness would hardly have been suspected." The greater similitude of the Miocene and Pliocene faunæ with the contemporaneous faunæ of the Old World, has led him to suggest that the North American continent was peopled, during the Tertiary Epoch, from the West. "Perhaps this latter extension," he continues, "occurred from a continent whose area now forms the bottom of the Pacific Ocean, and whose Tertiary fauna is now represented east and west by the fossil remains of America on the one hand, and of Asia, with its peninsula, Europe, on the other."

The topographical features of the two continents and the hydrographical soundings of the two oceans, render this supposition probable. Between Ireland and Newfoundland there is a great plateau, which an elevation of the earth's crust to the extent of a few thousand feet would convert into dry land; and Behring's Straits, which now separate Asia and North America, are, at their narrowest points, but thirty miles wide, and their shallowest depth is but twenty-five fathoms.

And here the palæontologist comes to the aid of the hydrographer, and, by their joint labors, the one renders probable what the other has conjectured as possible, — the former union of the two hemispheres. Zoölogy would indicate that such was the fact during the Pliocene Epoch, in which will probably be found the origin of those mammalian types contemporary with the elder man, and represented by the extinct Proboscidians and Ruminants. None of these large animals could probably have passed over the straits which now divide these regions, and the close alliance in form would indicate a common origin. We infer, therefore, that the subsidence during the Drift Epoch cut off the communication between the two hemispheres, and the refrigeration which then took place, served to disperse the colossal animals, who sought by migration to lower latitudes a climate congenial to their nature.

As in Europe, we find the remains of these northern types intermingled with those of an African type,— the hippopotamus, which in his summer migrations strayed as far north as England; so on this continent we had, during this epoch, the great sloths, represented by the megalonyx and mylodon, whose congeners at this time exist in South America. Thus there was an inosculation, so to speak, of two distinct and contemporaneous faunæ.

It is an inquiry of the highest interest, — perhaps as much so as any connected with the physical history of the past: How far has man been a witness of these stupendous changes? It is not until towards the close of the Drift Epoch, that we are enabled to detect unmistakable signs of his works, although there are not wanting proofs which would refer his origin to an earlier date, — the Pliocene. So numerous and well-attested are the facts, that we must now regard him as the contemporary of many of the great mammals which have ceased to exist, and the subject of physical conditions very different from what now prevail. To account for these changes requires the lapse of a longer period of time than has heretofore been assigned to his existence upon earth.

Thus within a few years has been opened a sphere of investigation which has enlisted a large class of able observers, and their labors have thrown a flood of light upon the origin of our race. Ethnography has become aggrandized into one of the noblest of sciences. However conflicting these revelations may be to our preconceived notions, they must not hereafter be disregarded in treating of the past and present condition of humanity. We must weigh the value of observations, and press them to legitimate con-

clusions. The investigator at this day is not to be trammelled, in the language of Humboldt, by "an assemblage of dogmas bequeathed from one age to another"—by "a physical philosophy made up of popular prejudices."

The periods of the prehistoric man have been divided by M. Lartet, into two ages,—

(1) The Stone Age, and (2) the Metal Age.

The Stone Age has been subdivided into three epochs.

1. That of the extinct animals, such as the mammoth and cave-bear.

2. That of the migrated existing animals (Reindeer Epoch).

3. That of the domesticated existing animals (Polished Stone Epoch).

The Metal Age has been divided into two epochs.

1. That of Bronze. 2. That of Iron.

The elder man differed widely from the intellectual and much-planning man of this day. The conditions of climate greatly modified his modes of thought and physical pursuits. The northern hemisphere was just emerging from a long-continued state of glaciation. The snows which had wrapped the earth as in a mantle, were melting, and the great glaciers were reluctantly retreating within the Arctic Circle. Every depression became a lake, and every lake a sea for the reception of the accumulating waters, whose resistless force swept along mud, and sand, and shingle, and fragments of rocks. As the barriers gave way, the waters cut out channels on their route to the sea, and the terraces and ridges which border our lakes and rivers are but the monuments of their erosive action. It was a sad and desolate land, to be paralleled only in the Arctic Circle. But man was not alone. On the European continent there was a strange assemblage of animals: the elephant, with his compound clothing of wool and hair; the rhinoceros, similarly protected; the cave-bear and cave-hyena; the tiger; and the great ox, not patient of toil as at this day, but fierce and indomitable. On this continent was the elephant of a closely allied species; the lion and bear, and at least two species of the musk-ox, gigantic as compared to their modern congener.

In such a climate and on such a soil we can well imagine that agriculture formed no part of the occupation of the primitive man. He gathered not the kindly fruits of the earth, but was essentially a predaceous animal. The few skulls that have been recovered, would indicate that he was low in the scale of intellectual organi-

zation, — a small brain, a retreating forehead, and oblique jaws. In capacity he was below the Australian and New Zealander. In stature he was dwarfed, but was broad-shouldered and robust, — the result of vigorous exertion and out-door exposure. He was carnivorous, and, perhaps, a raw flesh-eater; for in the jaws which have been disinterred, the incisor teeth are much worn, — a peculiarity which has been noticed in those of the flesh-eating Esquimaux. This fact ought not to be cited to his disadvantage, for in an Arctic climate where the animal heat is so rapidly abstracted, man requires a highly nitrogenous food. Thus we find our own countryman, Kane, when imprisoned in the ice of Rensselaer Harbor, resorting to raw walrus-meat, and rolling it as a sweet morsel under his tongue.

It cannot be gainsaid, however, that man was a cannibal. In Scotland were found the bones of children, which, according to Owen, bore upon them the marks of human teeth, and the evidences produced in the Archæological Congress at Copenhagen established this fact beyond controversy.

He was not destitute of skill in the art of delineation, for we have restored to us, on a slab of slate a very good profile of the great cave-bear — the earliest instance extant of pictorial representation.

But we must accord to him one redeeming trait. That homage which in all ages and among all nations, the living pay to the dead; those ceremonies which are observed at the hour of final separation; that care which is exerted to protect the manes from all profane intrusion; and those delicate acts, prompted by love or affection, which we fondly hope, will smooth the passage of the parting spirit to the happy land, — all these observances our rude ancestors maintained. These facts show that, deep as man may sink in barbarism, brutal as he may become in his instincts, there is still a redeeming spirit which prompts to higher aspirations, and that to him, even, there is no belief so dreary as that of utter annihilation.

Perhaps, among the existing tribes of the human race in the Arctic Highlander, as described by Sherard Osborn, we have the nearest approach to the prehistoric man: —

"Although dwarfed in stature, they are thick-set, strong-limbed, deep-chested, and base-voiced, and capable of vigorous and prolonged exertion. . . . I cannot discover an instance of their ever having been seen to partake of a single herb, grass, or berry, grown on shore. Of vegetables and cereals, they have of course no conception, and I know of no other people on the earth's surface who are thus entirely carnivorous."

After the lapse of a period whose interval cannot be measured, the great animals which characterized the dawn of the Human Epoch, began to disappear, and were replaced by other forms of diminished size, but of improved type. Among these, on the European continent, were the reindeer, the musk-ox, the stag, the bison, and urus, together with the horse, not distinguishable from the existing species. The reindeer and musk-ox, which only thrive in a cold climate, not only occupied England, but wandered as far south in France as the shores of the Mediterranean and the slopes of the Pyrenees, which interposed effectual barriers to their further progress.

The reindeer must have existed in vast herds, and to the primeval man have proved the most useful of animals. Every portion of the carcass was economized. His flesh furnished food; his skin, clothing; his sinews, thread; and his horns were fashioned into harpoons, javelins, and sockets for the reception of spear-heads and hatchets.

On this continent we find the musk-ox and reindeer, identical in species with the European forms, in a fossilized state. The reindeer ranged as far south as Kentucky and New Jersey, but the existing musk-ox has not been found fossilized outside of its present limits. The Boötherium, however, which exceeded him in size, and to which he was closely allied, had a range co-extensive with the reindeer. The stag (*Cervus alces*) and the bison (*B. latifrons*) were in existence, while the horse, which is abundantly represented in the Pliocene, and is continued into the Quaternary Period, had become extinct before the discovery of America. His remains are found in Eschscholtz Bay (latitude 66° 20′ North) in connection with those of the *Elephas primigenius*, the urus, deer, and musk-ox, imbedded in a deposit of clay and fine micaceous sand. The rhinoceros (*R. merianus*) appears in the Miocene of Texas, and is represented in the Pliocene of the Upper Missouri as *R. crassus*, and in the same formation in California as *R. hesperius;* but thus far the *Rhinoceros tichorhinus* so intimately associated with the great Proboscidians of Europe, has not, to my knowledge, been found in North America. In addition to these forms may be mentioned the great mastodon, which came into being subsequent to the elephant, and survived his extinction.

The fact of the existence of the mammoth or mastodon, was certainly known to the founders of the cities of Central America, for in more than one instance there is graven with elaborate care,

on the walls of their structures, the form of a Proboscidian, which cannot be mistaken for one or the other of these animals; but the works on which these delineations are made, indicate a far higher order of art than was ever attained by the prehistoric man of Europe. These delineations, I am disposed to think, are of the mastodon, and, found as they are upon the walls of stone-built palaces and temples, there is strong evidence to believe that this great Proboscidian survived almost to the Historic Period.

The men of the Reindeer Epoch made gradual advances in the industrial arts. They did not cultivate the soil, for the climate was still inhospitable. While their progenitors were content with knives flaked from flints in the form of rude fragments with cutting edges, they wrought out tools more symmetrical, but without any attempt at polishing.

They attained to a very creditable degree of artistic skill, as shown by their designs traced on tablets of ivory, and carved out of the antlers of the reindeer. We have thus represented the stag, the ibex, the horse, a reindeer couchant forming a dagger-hilt, and also the great elephant with his characteristic markings; the small oblique eye, the ponderous trunk, the recurved tusks, and the shaggy mane. The human form even is delineated. We have an ivory statuette of the female figure, and traced on a stag's horn the outline of a male figure with a caudal appendage like that which was conjectured by Lord Monboddo, the eccentric Scotch philosopher, to appertain to the primitive man.

On this continent the evidences of the existence of man at this age, while obscure, are yet, I am disposed to believe, authentic. The human bone found in the Loess at Natchez, and the flint implements found in connection with the Missouri mastodon, may claim as high an antiquity as the oldest of the European "finds."

The discoveries in California would seem to carry back the existence of man to a date still more remote. As early as 1857, Dr. C. F. Winslow sent to the Boston Natural History Society a fragment of a human cranium found in the "paydirt" in connection with the bones of the mastodon and elephant, one hundred and eighty feet below the surface of Table Mountain, California. It was in this region (Angelos, Calaveras County) that a human skull was subsequently found by a miner named James Matson in a shaft one hundred and fifty feet deep, which passed through five beds of lava and four deposits of auriferous gravel. The statements of Professor Whitney as to the authenticity of this skull have been

received with extreme distrust; but does not this earlier discovery of human remains in the same formation confirm the correctness of those statements?

Our country is yet new, and it is only recently that attention has been directed to these investigations. It is hardly to be expected that a competent observer will be present at the precise time when any relic of the past is disinterred; and there is an universal feeling of doubt and distrust as to the authenticity of all such finds. With the evidence before us that both hemispheres have been subjected to the same dynamic causes, and peopled by the same races of animals, often identical in species, is it not philosophical to infer that here we shall be able to detect the traces of man and his works, reaching back to as high an antiquity as on the European continent?

The Reindeer Epoch terminates the earliest known record in the career of man. It was signalized by a series of physical events too important to be slightly passed over. The glaciers again advanced, and again the land became refrigerated; but the cold period was not so long continued, and was less intense. To this succeeded a period of warmth, and as the glaciers dissolved under its influence, there ensued a flood which swept over the lowlands and forced the cave-dwellers to flee to the high grounds. The water in Belgium, according to Dupont, rose to the height of four hundred and fifty feet, and the calcareous mud, known as the Loess, was then deposited in the Rhine Valley. The caves were also invaded, and the "bone-earth" which forms the division between two distinct faunæ, is of the same age.

It was during this epoch that the great mammals disappeared from the earth,—the elephant, the rhinoceros, the cave-bear, the cave-hyena, the tiger, and the Irish stag; while the reindeer, the musk-ox, and the elk, migrated to the north where the changed conditions of climate were more congenial to their nature.

The musk-ox has disappeared from Europe, but he survives on this continent, restricted in his range to what are known as the "Barren Grounds," lying between the Welcome and Coppermine Mountains. The aurochs, protected by stringent laws, still survive, while the horse, domesticated by man, has vastly multiplied. The ure-ox, living through the great catastrophe, has disappeared within historical times.

The greatly augmented thickness of the Loess on this continent, would indicate that the ice action was exerted more powerfully,

and its effects are traced over a larger area; and the same destruction overtook the larger quadrupeds, extending even to the gigantic sloths, who lived in a milder climate.

From this era we may date a change in the physical conditions of our planet, so far at least as relates to the northern temperate zone. The climate became milder, and the soil yielded more bountifully those seeds and fruits which contribute to human support. Man for the first time began to show signs of progress in the industrial arts. His weapons of flint were more symmetrically fashioned, and in some instances were polished. The dog became his companion, and some of the other animals were domesticated. This was the Polished Stone Epoch.

In the Bronze Epoch we trace still greater advances. Man dwelt in fixed habitations. He surrounded himself with such domestic animals as the ox, horse, pig, goat, and sheep, and retained his companionship for the dog. He cultivated wheat and barley, whose flour he kneaded into bread and baked between heated stones. Apart from berries he gathered the fruits of the pear, cherry, and plum. The discovery of the art of smelting copper, and of the additional art of hardening it by a slight admixture of tin, was an immense stride towards civilization. Ere long followed the discovery of the art of iron-smelting, — a discovery which has done more to advance the welfare of our race than all others combined. Then it was that man, for the first time, was furnished with a weapon which enabled him to achieve a conquest over Nature, and this assertion will not appear extravagant when we reflect how intimately this metal is connected with all the industrial arts.

The Iron Epoch approaches so near the Historic Era that, as forming a portion of geological history, the events are too insignificant to be dwelt upon.

The Mound-builders of our own country, in the scale of civilization, were intermediate between the Polished Stone and the Bronze Epochs of Europe. They resided in towns, many of which have since become the sites of flourishing cities. They practised agriculture, making use of maize as their chief cereal; but there was not on this continent a domestic animal who could aid them in their labors or contribute to their sustenance. Strange as it may seem, that while the Danish kitchen-middins and the Swiss refuse-heaps contain abundant traces of mammalian bones, thus far they have been but rarely detected in the mounds. They chipped with great skill the limestone-chert into spades, spear-heads and arrow-

heads. Out of porphyry or greenstone they wrought their hatchets and battle-axes, and these were often ground and polished. The same material, too, was often used in making pipes, which were carved into forms representing quadrupeds and birds, so faithful in detail that the species to which they belonged can be identified. The specular iron ore of Missouri was elaborately wrought and polished into slung-shots or plummets. They mined extensively the native copper of Lake Superior, which they beat, and perhaps smelted, into knives, chisels, spear-heads, arrow-heads, and bracelets. They wove cloth with a regular warp and woof, out of a fibre as yet undetermined. They modelled clay into vases, water-coolers, and other utensils, and ornamented them with elaborate designs, and the human face, even, is portrayed with rare fidelity; and finally, they must have maintained an intercourse with distant and widely separated portions of the continent.

Since the close of the Reindeer Epoch the changes which have taken place in the flora and fauna of Europe have been slight. We may note, however, the disappearance of the Scotch fir (*Pinus sylvestris*) from Denmark, where it is found entombed in the peat-swamps, and the introduction of the sessile oak, which in turn is becoming supplanted by the common beech. In the Baltic the oyster flourished in places from which it is now excluded, and certain other marine forms that attained a full growth, are now dwarfed. There is an instance or two of the disappearance of mammalian forms, but this may be traced to the direct agency of man. These slight changes in physical geography have modified the distribution of animals and plants, but they have not affected, in the least, their form. Whatever changes have been observed are due to domestication.

So far as relates to our own country, there are evidences in the Great Basin and on the Colorado Plateau, that at no remote day there was a much more genial climate and a soil more productive than now prevail. This is seen in the dead forests that line the mountain sides; in the water lines of the lakes and streams high above the greatest floods; in the deep cañons through which now course trickling streams, but which must have formed the channels of voluminous rivers; and in the alluvial bottoms now bare and desolate, in which are imbedded the remains of a robust vegetation.

I have, perhaps, dwelt too long upon these changes which have so essentially modified the surface of the earth, and at the same time the destinies of our race. Had an Arctic climate continued

to prevail over what is now the temperate zone, man would have made no advance in civilization; life to him would have been a continued struggle for existence. It is only in a genial climate, and on a soil so generous as to yield with moderate exertion a support, that he can cultivate his intellect; and such culture, I need hardly affirm, is at the base of all civilization.

How great the contrast between the primitive cave-dweller and the practical man of to-day, who, availing himself of the conquests of science, subjects the forces of Nature to his will; who spans with bridges deep chasms; who stretches his iron rails over high summits; who traverses the trackless deep with unerring course; who flashes intelligence over a hemisphere. How different from the intellectual man of to-day, who weighs the earth as in a balance; who measures the distance of the sun and assays its elements; who maps the comet's path; who penetrates the deepest mysteries of the Universe. The one was almost a brute; the other is almost a god!

While these revolutions have taken place on the surface of the earth they have, at the same time, been sufficiently powerful to modify the marine fauna in the disappearance of old and the introduction of new forms to the depth of 1500 feet; but in the profounder abysses of the ocean, age after age, the conditions of life have remained comparatively unchanged. It is only within the past year that this interesting fact — a fact which must lead to a material modification of our previously formed views — has been prominently developed.

The soundings made as far back as 1857, over the great telegraphic plateau which stretches from Valentia to Newfoundland, disclosed in all instances a fine calcareous mud which entombed countless millions of shells belonging to the family of *Rhizopods*, and some peculiar bodies which are known as *Coccoliths* and *Coccospheres*, which were found to correspond with the organic contents of the true Cretaceous Period. In 1861, among a number of living mollusca and corals found adhering to a telegraphic cable between Algiers and Sardinia, taken up for repairs, Milne-Edwards detected certain shells which were only known as Tertiary fossils. In the same year Sars, the Swedish naturalist, described the *Rhizocrinus Lofotensis*, obtained on the Scandinavian coast, a new and living type of Crinoidea belonging to a family characteristic of the Oolite. The soundings, prosecuted under the direction of Count de Pourtales, attached to the United States Coast Survey, between

Florida and the outer edge of the Gulf Stream, have yielded important results which have been in part reported upon by de Pourtales, the elder and younger Agassiz, and Lyman.

The deep-sea dredgings prosecuted during the past year on board of her Britannic Majesty's ship Porcupine, placed at the disposal of a scientific committee consisting of Messrs. Carpenter, Jeffrys, and Thompson, have yielded results of the highest interest. The supposition of an Azoic zone must now be abandoned. The profoundest depths of the ocean, in which the Himalayas or the Andes might be engulfed, are now believed to be inhabited, and inhabited, too, by organic forms which, since the dawn of the Cretaceous Age, have undergone no considerable modification. The littoral deposits, on the other hand, show the most marked diversities in organic forms. In one sense, as declared by Dr. Carpenter, we are living in the Cretaceous Age; in another, since the close of that age we have witnessed repeated dispersions and modifications of organic forms.

Dr. Wyville Thompson, generalizing on these facts, says that there is no direct evidence that oscillations have taken place in the Northern Atlantic greater than 1500 feet since the commencement of the Mesozoic Period, and that the great depressions in the Pacific and Atlantic Oceans are due to causes that acted before that period.

"There have been," he continues, "constant minor oscillations; but the beds formed during periods of depression, but now exposed by an upheaval of this minor character, are comparatively local and shallow water beds, as shown by the nature and richness of their fauna."

The dredgings which have been made in the fresh-water lakes of high northern latitudes have proved of equal interest. In the Swedish lakes, Wetersee and Wenersee, have lately been discovered crustacea which, though differing from those now living in the sea, are clearly related to marine forms of a northern and even Arctic character. Thus have been found the *Mysis relicta*, whose congeners live altogether in the sea, and those resembling the species in the most northern latitudes; the *Gammarius loricatus* thus far found only in the Arctic Ocean, Baffin's Bay, Greenland, and Spitzbergen; the *Idothea entomon*, in the Arctic Ocean and the Baltic Sea; and the *Pontoporcia affinis*, still found in the Baltic, but whose related species occur in the Greenland seas. These lakes are three hundred feet above the sea-level; but these

results show that at no remote day they communicated with the ocean, and were originally tenanted by a marine fauna of an Arctic type. As these waters became first brackish and then fresh, most of the forms died out during the transition, leaving in the depths a few crustacea which correspond in part to the species in the Baltic, and in part to those of the Arctic Ocean.

Within the past year Dr. Stimpson has obtained results equally interesting, from dredgings brought up from the deeper parts of Lake Michigan. The lake-level is five hundred and eighty-three feet above the ocean, and the greatest depths extend below that line. At the depth of sixty fathoms he obtained a *Mysis*, which, although not specifically identical with the Swedish form, is closely allied, and its occurrence authorizes us to draw the same conclusions as to the marine character in former times of the Great Lakes, which the Swedish physicists have arrived at as to the former condition of their own.

Much discussion has been had in former years, and even in this Association, as to the nature of these lake waters during the Glacial Age. It is well known that on the borders of Lake Champlain, and at intervals along the St. Lawrence from Quebec to Kingston, and up the Ottawa, the terraces attaining an extreme height of between four hundred and five hundred feet, contain marine remains; but when we pass over into the Great Lake basin, these remains disappear. Hence it has been inferred that, at that time, as now, the Great Lakes were filled with fresh water: but the discoveries of Dr. Stimpson, I think, disprove the correctness of this inference; and further discoveries may show that these lakes formerly had communication, not only with the Atlantic through the St. Lawrence, but with the Arctic Ocean through Hudson's Bay.

We are now led to the inquiry: What has caused these great changes of temperature, affecting the whole economy of terrestrial life? Between the Arctic and Antarctic regions there are great diversities of climate and physical conditions. The one is characterized by a vast expanse of land, and the other by a vast expanse of ocean. The one enjoys a short-lived summer, in which the flowers blossom and fructify; in the other reigns unmitigated winter, and even mosses and lichens are absent. In the one, the reindeer and musk-ox are hunted to the verge of the sea; in the other, animal life disappears below latitude 56°. Man has been able to penetrate North to 82° 40′ 30″, or within nearly five hundred miles of the pole; but to the south he has only reached 78° 10′, or about eight hundred and fifty miles.

There are several causes which combine to produce this result. The great continental masses which characterize the northern hemisphere, warmed by summer sun, radiate heat into surrounding space, while the narrow expanse of land in the Antarctic circle, bathed by chilled waters, and encased in ice, acts as a refrigerator of the atmosphere. Besides, as we shall hereafter show, owing to the earth's movement, the southern summer is shorter by at least eight days, and the amount of heat received during that period by the northern hemisphere cannot but exert an appreciable influence. The Arctic region, then, enjoys a milder climate than it would if, as in the Drift Epoch, it were submerged to the depth of at least two thousand feet. In the Great Year of astronomers, the southern pole, after having passed through its great winter solstice, is now entering upon its summer climate.

Lyell has conjectured that these phenomena are due to a different distribution of land and water, combined with a different distribution of oceanic currents; but with an expanse of land occupying almost the whole of the northern hemisphere, and with the Gulf-stream diffusing its warm breath over the western coast of Europe, and the Japan Current over the western coast of America, we find that the domain of ice and snow remains fixed; and we can conceive of no conditions, dependent upon these causes, whereby the *Cinnamonium* should again flourish at Bellingham Bay, or the *Sequoia* on the Greenland coast.

Others have inferred that these great cycles of warmth and cold may be due to the increased or diminished heat transmitted from the interior of the earth. If we adopt the theory of a cooling globe, there must have lapsed a very considerable period between the time when it passed from an incandescent state and when it became fitted for the sustenance of organic forms. Sir William Thompson, basing his observations on the well-known laws of heat and conservation of energy, infers that it has only been habitable within the last one hundred millions of years. It is then, if his estimates be true, within this interval that we are to include all the changes in the organic world,—the floræ and faunæ which have successively come into being, and have successively displaced each other.

In the process of solidification the earth is supposed long ago to have arrived at that stage when the radiation from the cooling surface is no greater than that derived from the sun, and, therefore, a stable temperature has been established. We would infer, then,

that any violent reaction of the interior upon the exterior crust, would affect more sensibly the deep-sea animals than those dwelling on the land; but the investigations which I have cited, show that while the sea fauna has undergone slight modifications since the dawn of the Cretaceous Epoch, the land fauna has been subjected to the most marked deviations.

May not, then, these fluctuations of temperature be due to causes which operate from the exterior? Is it necessary to assume that, throughout the lapse of all time, our planet has occupied its present relation to the sun, or the solar system? Is not the recession of Sirius, which is now going on, an argument against the fixity of the siderial heavens?

We are assured that ours is not a central sun, but one in the great procession of stars which is sweeping towards the constellation Hercules: and that in the region of ether there are spaces of densely clustered stars, and other spaces which are comparatively barren. Now every star is a sun, emitting light and heat, a portion of which is transmitted to us. Our planet at this time is moving through one of those starless spaces, and therefore is not in a position to receive the full influence of such a cause. The distinguished Swiss botanist, Heer, to whom we are so largely indebted for our knowledge of the Miocene flora, has suggested that it is to this source rather than to telluric causes we are to resort to explain the varying distribution of temperature as manifested in past geological times.

Again: Have we the right to assume that, throughout all past ages, the poles of our planet have pointed in the same direction? We can conceive that, if its axis were to form with the plane of the ecliptic, the same angle which it now forms with the equatorial plane, there would ensue an entire change of climate, and consequently of organic forms. Why should the astronomer insist on the immutability of the siderial system, when to the geologist is unfolded a record of seas displaced and continents elevated; of great cycles of heat and cold; of the disappearance of old, and the appearance of new forms of organic life? Change, not constancy, is inscribed on every leaf in the volume of Nature.

I am not a believer in the doctrine of multiplied shocks. I would not, in the explanation of natural phenomena, resort to blind catastrophes. But is there not behind all, and over all, and pervading all, a great governing principle to whose operation we can refer these changes? Does it not exist in the celestial mechanism

itself? To the solution of this problem the attention of several physicists has been directed.

The speculations of the French savant, Adhemar, are not altogether to be overlooked, based as they are on the precession of the equinoxes and the movement of the apsides; a movement which, I believe, was unknown to the elder astronomers. If we compare the movement of the earth with the stars, it requires the lapse of 25,000 years to bring the equinox to correspond with the same point in space it now occupies; but the orbit itself being movable, this period is reduced to about 21,000 years. This is called the Great Year, being the measure of time before the winter solstice will again exactly coincide with the *perihelion*, and the summer solstice with the *aphelion*, and before the seasons will again harmonize with the same points of the terrestrial orbit.

The earth, at this time, approaches nearest the sun in the northern hemisphere during autumn and winter, and it is only when it recedes the farthest from the source of heat that the northern hemisphere receives the full effect of its vivifying warmth. As the earth between the vernal and autumnal equinox traverses a longer circuit than during the other half of the year, and also experiences an accelerated movement as it draws near the sun, the result is, that the northern summer is longer than the southern by about eight days; but after the lapse of 10,500 years these conditions will be reversed. It was in the year 1248, according to Adhemar, that the Great Northern Summer culminated, since which time it has continued to decrease, and that decrease will go on until the year 11,748, when it will have attained its maximum.

This compound movement, the precession of the equinoxes and the shifting of the line of apsides, it is claimed, exerts a marked influence in the distribution of the earth's temperature. While the Great Winter prevails at the north pole, the refrigeration is so excessive that the heats of summer are insufficient to melt the snow and ice precipitated during the winter, and hence, year after year, and century after century, they go on accumulating, until the circumpolar region is in a state of glaciation, and the added weight becomes sufficient to displace the centre of gravity, which would be equivalent to a subsidence at one pole, and an elevation at the other. M. Adhemar has even calculated the extent of this movement, and states that it would amount to about 5500 feet. Now, let it be borne in mind that Professor Ramsey has shown that in Wales the submergence of the land during the Drift Epoch

amounted to 2300 feet, and our own observations show that in the northern portions of this country the glacial action proper may be traced to the height of 2000 feet; although there were mountains which served as radiating centres, on whose flanks the Drift action may be traced much higher. These geographical points, roughly estimated, are about midway between the equator and the pole, and the extent of the subsidence would correspond very well with the calculations before referred to.

In the year 1248, the Great Winter terminated at the south pole, where for 10,500 years the accumulation of snow and ice had been going on, attended with the phenomena which we have described. "Here then," says M. Julien, an advocate of this theory, "is an irresistible force which, following the invariable law of the irregular precession of the equinoxes, must make the earth's centre of gravity periodically oscillate."

Mr. Croll, an English physicist, has elaborately discussed this question in a series of papers in the "Edinburgh New Philosophical Magazine," which have excited profound attention. With great labor he has prepared tables showing the amount of the earth's eccentricity for the period of three millions of years, at intervals of 10,000 years for a greater portion of that time, and 50,000 years for the remainder. He infers that a glacial period occurs when the eccentricity of the earth's orbit is at a maximum, and the solstices fall when the earth is *in perihelio* and *in aphelio;* and that only one hemisphere has a glacial climate at the same time, which occurs when the winter is *in aphelio.*

In this connection I may mention the labors of our own countryman, Mr. Stockwell, who has prepared a paper, now on file in the Smithsonian Institution, embodying his own calculations as to the earth's eccentricity for the past two millions of years.

There is such an intimate connection between the several branches of science, that the researches in one field often throw light upon the obscure points in another. In the solution of this difficult problem, the geologist may invoke, and I trust not unsuccessfully, the aid of the astronomer.

That a set of causes were active during the Drift Epoch, in one hemisphere, which remained dormant in the other, admits of little doubt; and the advocates of the astronomical theory, as evidences of the shifting of vast amounts of water from one pole to the other, point to the marked differences in the topographical features of the two hemispheres. In the Austral region we meet with pro-

jecting headlands and peninsula-like terminations of continents, and groups and chains of islands in the Pacific and Indian Oceans extending over vast areas, which rise up like the peaks and crests of mountains. These are the evidences of a gradually engulfed hemisphere. In the Boreal region we have wide expanses of land diversified by mountains, prairies, and plains; elevated sea-beaches and river-terraces, most conspicuously displayed on the borders of the Arctic Sea; vast oceanic shoals; a marine fauna of a northern type preserved in beds of 1400 feet, and stratified beds of gravel and sand, 2000 feet above the ocean-level; clusters of lakes yet retaining their bitter waters; shallow seas once salt, but each decade becoming more brackish; vast desert tracts which up to a recent time formed the ocean bed; — all these phenomena indicate a hemisphere gradually emerging from the waters. Perhaps the physicist can discern in these great periodic oscillations, the method by which Nature perpetually renews the youth of our planet, and maintains its fertility.

Gentlemen of the American Association, — The hour, which, in your courtesy, had been assigned to me, has now lapsed, and I must bring these remarks to a close. The topics which have passed under review open up spheres of thought with regard to time and space too vast to be compressed within the limits of a mere oral discourse. Asserting no ability by reason of profound research to pass authoritatively on these results, may I not inquire: Have they not disclosed new paths in the great domain of Nature, which may be profitably explored jointly by the geologist and the astronomer; and is there not a probability that there will be found to exist an intimate relation between the periodic fluctuations of temperature on our planet, and the periodic perturbations to which it is subjected as a part of the solar system? Great as have been our achievements in science during the past, we profoundly believe that new triumphs await the patient observer.

PROCEEDINGS

OF THE

TROY MEETING, 1870.

COMMUNICATIONS.

A. MATHEMATICS, PHYSICS, AND CHEMISTRY.

I. MATHEMATICS AND ASTRONOMY.

1. NOTE ON CERTAIN INVOLUTES OF A CIRCLE, AND ON THE ANALYTICAL VALUE OF THE HYPERBOLIC BASE. By THOMAS HILL, of Waltham, Mass.

I HAVE been investigating the meaning of the equation $y = Ax^n$ when x and y are not rectilinear coördinates. The result obtained in Peirce's Circular Coördinates is the subject of the present note.

The equation

$$\varrho_n = \frac{R}{n!}\nu^n, \quad (1)$$

evidently represents the nth involute of a circle, the constant of integration having been always made equal to zero.

The length of the arc of this involute is

$$S_n = \frac{R}{(n+1)n!}\nu^{n+1} = \frac{\nu}{n+1}\varrho_n, \quad (2).$$

If now in (2) we make $n = \infty$ and $\nu = n + \mu$ we get, while μ remains finite, $S_n = \varrho_n$, which would seem an equation of a logarithmic spiral; but the substitution of the same values in (1) renders that equation infinite of the form

$$\varrho_n = R\frac{(n+\mu)^n}{n!} = R\frac{n^n}{n!} = Re^n \quad (3).$$

We must, therefore, assume $\nu = \frac{n+\mu}{e}$ which gives $\varrho_n = R = e\, S_n$, which is a logarithmic spiral.

I am not aware that the lemma $n^n = e^n\, n!$ has ever been published.

The lemma $n\,(n!)^{-1/n} = e$ I have demonstrated by three processes. For the following neat form I am indebted to Professor F. W. Bardwell, of Kansas: —

(4). Let us adopt the notation

$$\Sigma\,(n^m) = 1^m + 2^m + 3^m + \&c. + n^m,$$

(5). For $n = \infty$ this becomes $\Sigma\,(n^m) = \frac{n^{m+1}}{m+1}$.

(6). Putting x for the second member of the lemma, and involving, we can deduce

$$\frac{1}{x^n} = \frac{n!}{n^n} = \frac{1}{n} \cdot \frac{2}{n} \cdot \frac{3}{n} \cdot \ldots\ldots \frac{n}{n},$$

(7). And by inverting the order

$$\frac{1}{x^n} = 1\left(1 - \frac{1}{n}\right)\left(1 - \frac{2}{n}\right)\left(1 - \frac{3}{n}\right) \cdots\cdots \left(1 - \frac{n-1}{n}\right).$$

(8). The logarithm of (7), whatever the value of n, gives us

$$\begin{aligned} n \log. x = & \tfrac{1}{n} + \tfrac{1}{2}\left(\tfrac{1}{n}\right)^2 + \tfrac{1}{3}\left(\tfrac{1}{n}\right)^3 + \&c. \\ & + \tfrac{2}{n} + \tfrac{1}{2}\left(\tfrac{2}{n}\right)^2 + \tfrac{1}{3}\left(\tfrac{2}{n}\right)^3 + \&c. \\ & + \tfrac{3}{n} + \tfrac{1}{2}\left(\tfrac{3}{n}\right)^2 + \tfrac{1}{3}\left(\tfrac{3}{n}\right)^3 + \&c. \\ & + \&c. + \&c. \ \ldots\ldots \end{aligned}$$

(9). Summing the vertical columns in (8) gives, by (4), and dividing by n,

$$\log x = \frac{\Sigma n}{n^2} + \frac{1}{2}\,\frac{\Sigma\,(n^2)}{n^3} + \frac{1}{3}\,\frac{\Sigma\,(n^3)}{n^4} + \&c.$$

(10). And when n is infinite we have by (5),

$$\log. x = \tfrac{1}{2} + \tfrac{1}{2.3} + \tfrac{1}{3.4} + \tfrac{1}{4.5} + \&c = 1.$$

Whence $x = e$, *quod erat demonstrandum.*

It is to be observed that I here discuss only integral values of n; fractional values give entirely different curves.

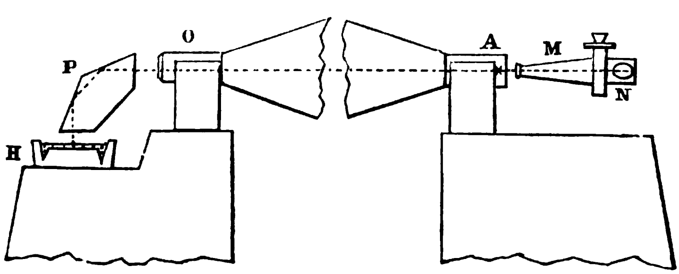
2. On a New Method of Determining the Level-Error of the Axis of a Meridian Instrument. By C. A. Young, of Hanover, N. H.

The inclination of the axis of a meridian instrument to a horizontal plane has hitherto been measured by three different methods: by the use of the spirit level; by examining with a collimating eye-piece the image of the wires as in nadir-point observations, the collimation having been previously determined either by reversal of the instrument or by collimators; and lastly by observing the transits of stars by reflection from an artificial horizon.

The first of these methods is by far the most used, and with portable instruments is sufficiently convenient. Still it requires a good deal of time, and, in the case of a large instrument, of hard work; and if there are sensible irregularities upon the pivots of the instrument it is a very troublesome operation to ascertain and apply the necessary corrections.

The second and third methods are still more laborious: the second gives the level error corresponding to but one single position of the telescope, *i. e.*, with the telescope pointing downward, and is therefore liable to a constant error depending upon any malformation of the pivots which affects the instrument in this particular position; the third method can be used only when the air is perfectly still.

The method I have to propose allows the determination of this error without any further labor than two readings of a microscope, in any position of the telescope, and without that uncomfortable climbing which is involved in the use of the striding level or nadir observations. The arrangement of the apparatus is illustrated by the annexed diagram, in which, however, no regard is paid to the



relative proportion of parts; the prism and mercurial horizon being grossly exaggerated in size for the sake of distinctness.

The axis of the instrument is to be fitted up as a collimator in the same manner already practised by Challis, Airy, and others. In place of cross-wires, however, the extremity *A* should be provided with a plate of thin glass having a minute dot or circle engraved upon it, the plate being adjustable so that this dot can be brought into the geometrical axis of revolution and into the focus of the small object-glass which is situated in the other pivot, *O*. A reading microscope, *M*, is attached to the pier and provided with an ordinary collimating eye-piece *N*, by which light can be thrown upon the dot through the tube of the microscope. This enables us to measure the vertical distance between the dot and its image formed by reflection in the manner to be described.

Opposite *O* is fixed a prism shaped like that of a camera lucida, which by *two* total reflections bends the light through a right angle. Immediately below it is placed a mercurial horizon. If an ordinary right angled prism were employed, producing the bend by a *single* reflection, then any disturbance of the prism would disturb twice as much the relation between the ray passing from *A* to *O* and that returning; but with a prism of the form proposed this relation is independent of any small changes in the position of the prism. Distortion of the prism, which is hardly to be feared, could alone do any harm.

A prism of this form and mercurial horizon, thus combined, form in effect a vertical plane mirror, whose verticality is independent of any small instability of the pier upon which it is mounted.

It is then easy to see that if the dot be accurately centred, and if the axis is level, the image of the dot will exactly coincide with the dot itself, provided that the reflecting angle of the prism be exactly 135°. If, however, the angle vary slightly from this, the image of the dot will fall above or below the dot itself by a small amount, which will be constant, and can be determined once for all by any one of several different methods. Any deviation of the axis from horizontality will immediately be indicated by a change in this distance twice as large as the deviation itself, and may be accurately measured by the microscope. Inaccuracy in the centring of the dot is eliminated by taking two measurements in opposite positions of the telescope.

The mercurial horizon employed should of course be so devised as to be free from tremors as far as possible. The form recently

described by J. H. Lane, of the U. S. Coast Survey, appears to leave little to be desired in this respect.

There is no difficulty in arranging the apparatus so that the ordinary illumination of the wires at the eye-piece of the telescope shall be effected by the light transmitted through the body of the microscope. So arranged, the apparatus remains in constant readiness for use, and, as before remarked, requires only the labor of taking two microscope readings for each determination of level error, without involving any disturbance of the setting of the instrument.

I may add in closing, that this virtual mirror of constant inclination to the horizon may easily find other applications, — as for instance in determining the horizontal points of a vertical circle where the object glass of the instrument is not so large as to require a too unwieldy and expensive prism.

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3. The Discovery of the Force which originally imparted all their Motions to all the Stars. By Jacob Ennis, of Philadelphia, Penn.

This paper is devoted to the force which in the beginning imparted all their motions to all the stars. The stellar velocities are among the grandest wonders of modern science. Our sun revolves in an unknown orbit at the rate of four hundred and twenty-two thousand miles per day, carrying along his beautiful halo of planets and satellites; while at the same time this, our earth, is hastening around the sun with a velocity of more than a thousand miles a minute. The star 61 Cygni moves more than two thousand, and Arcturus about three thousand miles per minute. In the history of science it is a remarkable fact that no inquiry has been made about the force which has produced these mighty movements. We are awed with a feeling of astonishment almost overcoming our faculties when we reflect on the unseen power which could send through space such great globes with such inconceivable velocities. Hence all that has been said about the origin of these stellar volocities is, that they could not have originated from the force of gravity; and this assertion has often been repeated.

After reflecting a long time on this wonder, it has been my fortune to discover that gravity is, indeed, the force which, in the

beginning, put all the heavens and the earth in motion. The method by which I made this discovery was by the study of the nebular theory. As by the study of the Copernican theory Newton discovered that gravity is the force which now holds all the stars in their orbits, so by the study of the nebular theory the discovery has now been made that gravity is the force which originally gave all the stars their motions in those same orbits.

The nebular theory, as understood by myself, supposes all matter to have been diffused nearly equally through all space. This diffusion of matter could not have been perfectly even; for that would have been a condition beyond our experience among the fluids of creation. The air is not perfectly even in its densities, nor the aqueous vapor in the air, nor the waters of the ocean. Some of the mightiest marine currents flow from these unequal oceanic densities. After this diffusion of matter through all space, contraction began. This contraction was caused by chemical combination; but the proofs of this cause need not be considered now. Whatever might have been the cause of contraction, I am now to prove that gravity, acting on the slowly condensing fluid, was the great instrument in the hand of Omnipotence which moulded the stars, arranged them in systems, placed them in their orbits, and gave them their wonderful velocities. This is saying great things for gravity, and the announcement may look too wide and sweeping. But the proofs of this great truth are clear and easy. I will advance them one by one in numerical order.

1. When the original diffusion of nebulous matter began to contract, gravity would gather the rarer portions around the denser, and thus separate the whole into many different portions, like the numerous clouds which sail by on a summer day when the vapor in the air is condensing. Such clouds are naturally different in size, irregular in shape, and at unequal distances apart. Sir Isaac Newton says that "if matter were evenly diffused through a finite space, and endowed with innate gravity, it would fall down in the middle of the space, and form one great spherical mass; but if matter were diffused through infinite space, some of it would collect into one mass, and some in another, so as to form an infinite number of great masses. In this manner the sun and stars might be formed, if the matter were of a lucid nature."

2. From the different sizes and unequal distances apart of the primitive nebulous clouds, it would happen that they would fall into one another. Those which were near would, by gravity, be

drawn together; and the smaller would fall into the larger. But in no case could one ever be struck by another in the direction of the centre of gravity. The falling body would necessarily be under the influence of other neighboring bodies; and, being thus drawn out of its direct course, it would strike obliquely. If with the blow of a hammer we strike a suspended ball in the direction of its centre, it will fly straight onward. If we strike it obliquely, it will spin around. In like manner the nebulous body when struck obliquely would enter upon a rotation.

3. Rotation would begin not only from the different sizes and unequal distances apart of the primitive clouds: it would begin also through gravity from their irregular shapes. Clouds have angular projections, long drawn-out arms, nearly detached outliers. Gravity would bring all these irregularities down to the level of rotundity. But these projections and arms and outliers would, as they fell, be also under the influence of gravity from the neighboring clouds. Hence they would come down obliquely, and these oblique falls would lead to rotation. They would at first produce several lateral currents, running in different directions on the surface of the nebulous globe. But by the composition of forces these different currents must ultimately coalesce into one; and this current around the new-born globe would be its rotation. But such surface currents would form only a rotation on the surface: even a small cloud falling into a larger one very obliquely would produce only a surface rotation.

4. This surface rotation would be *retarded* by friction on the unrotating interior. This retardation would be greater or smaller in proportion as the unrotating interior were greater or smaller. But, whatever be the amount of retardation, the momentum of rotation would not be lessened; because the momentum lost by the exterior would be gained by the interior; and in this manner the entire globe must rotate.

5. But, from the very beginning, the amount of rotation would be continually increasing, on account of the continued contraction of the nebulous globe. The contraction of the globe would increase the amount and velocity of rotation in this way: Every particle of a globe, as it went forward, went also downward toward the centre by contraction. They would all, therefore, take the direction of an inclined plane, and go down all the while faster and faster, according to the law of descent down an inclined plane.

6. But the velocity down an inclined plane is calculable; and, therefore, the velocity of rotation is calculable. A ball rolling

down an inclined plane gains the same velocity, friction excepted, as when it falls through the height of the plane. And a particle on the equator of a nebulous globe, going round and round, no matter how often, down any distance toward the centre of the globe, gains the same velocity, friction excepted, as if it should fall directly down equally near to the centre. In calculating the increasing velocity of such a perpendicular fall, we really calculate the increasing velocity of rotation, always excepting friction.*

7. But how rapid can this velocity of rotation become? In all

* For instance, in the nebula forming our solar system, there was necessary a rotation with a velocity equal to the present orbital velocities of the several planets when the surface of the nebula had contracted to their orbits. I have demonstrated mathematically that the velocity of a fall from infinite space to the orbit of any planet is to the orbital velocity of the planet as 100 is to 70, very nearly. Infinite space is taken for a convenient approximation, because the attraction of a body at vast distances becomes so exceedingly small. A mass of matter which would be attracted by the sun with the force of 409,000,000 pounds at the sun's surface, would be attracted with the force of 902 pounds at the earth's orbit, and of only one pound at the orbit of Neptune. It would be attracted with only the one-hundredth part of an ounce at forty times the distance of Neptune. I have shown that, if our nebulous sun had a velocity of rotation of only the one-third of a mile per hour at its greatest expansion, say half the distance of the nearest fixed star, then, according to the law of "rotation areas" — the radius vector sweeping over equal areas in equal times — at the orbit of Mercury it must have a velocity of rotation equal to the orbital velocity of that planet,— namely 110,000 miles per hour. It is generally known that, if our earth should contract in volume, it must also increase its velocity of rotation. But it seems not to be generally known that this increase of velocity would be *caused solely by the force of gravity* in hurrying every particle of the globe down an inclined course toward the centre.

If the velocity of a fall from infinite space to any orbital velocity be as 100 to 70, then it may be objected that the force of gravity is too great to be the force which gave their velocities to the stars. To this it may be replied: 1st. That no rotation of any nebula actually began off at infinite space: large contraction must have taken place before rotation began; 2d. That rotation began generally on the exterior, and the velocity was *retarded* by friction on the interior. In the case of our solar system, I have proved that this retardation between the orbits of Neptune and Uranus was one per cent. in a contraction of 250,000,000 miles in diameter of our nebulous sun: so nearly does the actual velocity of Uranus agree with its velocity as due to the force of gravity.

This paper is designed to present not the mathematical calculations leading to these results — for that would go far to fill this volume — but only the results themselves stated concisely, in distinct propositions, in their widest generality, and in their most logical sequence. This has never been done before. Moreover, many things are here brought out, which are not referrred to in "The Origin of the Stars," or in my papers in the Proceedings of the Academy of Natural Sciences, Philadelphia, for 1867.

vastly extended nebulous globes, this velocity of rotation may reach a certain definite limit beyond which it cannot increase. This limit is when the rotation becomes so rapid that the centrifugal equals the centripetal force. This limit is first reached by the matter on the equatorial zone of the nebulous globe, because there the centrifugal force is always greatest, and the centripetal force is always least. This zone of equal force must always be narrow, because of the extreme oblateness of the swiftly rotating nebulous globes: their equatorial being to their polar diameters nearly as two to one. Therefore a narrow and shallow equatorial zone, being equally balanced between two forces, cannot descend any nearer toward the centre of the globe, and hence cannot increase its velocity. But the matter next beneath that zone may descend and increase its velocity until it becomes equipoised; and, so on, layer after layer arrives at the point of equipoise where it can no longer descend, and no longer acquire additional velocity. Hence these layers must be abandoned by the contracting interior, and separated from the globe.

8. If the nebulous globe be homogeneous in its density, then the matter on the equatorial zone will be constantly arriving at the point of equipoise, and constantly abandoned by the contracting globe. These rings may be very near to one another, so that, taking all together, from the outer to the inner, they may form a nearly continuous disk.

9. If the globe be not homogeneous in its density, if the outer strata, independent of pressure, be less dense than the interior,—then the several strata will be separated from the interior globe at wide intervals from one another, and the succession of rings encircling the globe will be far apart. No close disk-like series can then be formed. This was the case with our nebulous sun.

10. If in any nebulous globe rotation begins with a thin layer on the exterior, and if the globe be not greatly expanded, then retardation will be great and the distance for contraction will be small. Therefore a velocity of rotation may never be attained so great that the centrifugal may equal the centripetal force. From such nebulous globes no equatorial rings can be separated; and such formerly were Mars, Venus, and Mercury. They abandoned no nebulous rings which might subside into satellites.

11. If the initial velocity be not merely in an external layer, but a general movement through the entire globe, and if the globe be very greatly expanded, then all the matter of the globe may be separated in a disk-like succession of rings.

12. Between these two extremes, there may be an infinite number of intermediate grades; none of the matter may be separated, or a small part may be separated; then larger and larger portions may be separated; until finally all the matter of the globe may be spread out in a disk-like succession of rings.

13. By continued contraction all the rings must break up into separate nebulous clouds, in the same manner and for the same reason as did the nebulous matter originally diffused through all space. Here we contemplate two successive sets of nebulous clouds. We may call the first in the order of time the PRIMARY NEBULÆ, and the next the SECONDARY NEBULÆ. The secondary nebulæ must also rotate and give off rings. These latter rings must also break and form TERTIARY NEBULÆ, which in turn must rotate and again produce rings and QUATERNARY NEBULÆ. The primary nebulæ formed sidereal systems; the secondary nebulæ formed solar systems which revolve within sidereal systems; the tertiary nebulæ formed planetary systems which revolve within solar systems; the quaternary nebulæ in our solar system have condensed into satellites or moons. There are solar systems a hundred times larger than our own, and in these great systems the quaternary nebulæ have probably given rise to a fifth or a sixth series of nebulæ.

14. We have now arrived at a point in which we behold how gravity has caused both rotundity and rotation; how, through this velocity of rotation, gravity has produced a centrifugal force acting antagonistic to itself; how by this centrifugal force it has separated rings from interior contracting globes; how gravity has collected these rings into round rotating bodies, which by further contraction have settled into stars. Here we behold how the rotations and the revolutions of the stars are plainly due to gravity and to gravity alone. Therefore we have our position clearly proved, that gravity acting on slowly condensing nebulous matter was the great instrument which moulded the stars, arranged them in systems, placed them in their orbits, and gave them their wonderful velocities. But our proofs of the originating and formative agency of gravity do not stop here. We follow them on to show how gravity has given origin to a vast number of strange phenomena, which meet the gaze of astronomers in the many systems of stars which in every direction animate the boundless realm of space.

15. The forms of all the systems of stars are infinitely varied. Probably, like the trees of the forest and the faces of men, no two

are alike. This has arisen from the fundamental fact, that no two clouds are alike, whether the clouds be nebulous in the beginning, or vaporous now in our atmosphere. They differ in size, in shape, in density, and in distances apart; and all these four elements must have contributed to vary the systems of stars. The sidereal systems, on account of their great distances, appear like mere patches of light, and hence they are called nebulæ. The telescope resolves many of them into stars; but no telescope can ever resolve them all, because the infinity of space can never be reached and explored by a finite instrument.

Some spectroscopists have lately announced that a few of the nebulæ (sidereal systems) are really great masses of gas in a blaze. This is a mistake; and it has arisen from the fact that some sidereal systems are so distant that the light of their individual stars can make no impression on the sight, even with the aid of the most powerful instruments. Their light arrives in a collected mass, like that from a gaseous diffusion; and its action on the spectroscope must in both cases be alike. The light from incandescent solids and gases differs in this, — the luminous particles of solids are close together; those of gases are far apart. Hence their difference by the spectroscope. But, in the far distant sidereal systems, the angular distances of the several stars must be somewhat similar to the angular distances of the luminous particles of a gas near by; hence their resemblance by the spectroscope. But this question is decidedly ended by the fact that some of those very nebulæ, which give the gaseous lines by the spectroscope, have been resolved into individual stars by the aid of very powerful telescopes; thus proving that they are not gaseous.

16. When a great disk of nebulous matter, formed from a primary nebula, and evenly spread out from the centre to the circumference, broke up by contraction into a system of stars, then these stars would be evenly distributed through every part of the disk-like system; and such sidereal systems, now appearing in the heavens, are called PLANETARY NEBULÆ. When the rings were closer together toward the centre, then the resulting stars would be more thickly clustered there; and such sidereal systems now in view are called ELLIPTICAL NEBULÆ. When the nebulous matter was not all thrown off in equipoise between centrifugal and centripetal forces, then a large mass might settle in the form of a great star at the centre. Such sidereal systems now appear like a huge star encircled with a dim haze, which haze is composed of the small

stars of the disk. These sidereal systems are called NEBULOUS STARS.

17. There may be rotations of fluids where, by centrifugal force, all the matter is driven from the centre towards the circumference. We see this in the whirlpool, and in the whirlwind or tornado. In the tornado the central vacuum may be so nearly complete that water will rise in the centre several feet, and spray and mist even to the clouds. But so violent a rotation can never be produced, except by great external force. As the paddle strongly propelled through the water may make deep dimples, and as the concussion of opposing currents of air may cause tornadoes with a central vacuum more or less complete, — so the primitive nebulous clouds might, through gravity, rush together with a rotation violent enough to throw nearly all their material from the centre to the circumference, leaving it there as a great thick ring, suspended in equipoise between centrifugal and centripetal forces. Then, in the process of contraction, this great ring would break up into many smaller nebulæ; and, as these subsided into stars, those stars would be disposed around in a ring-like form. Sidereal systems, appearing now in the remote depths of space in the form of a ring, are called ANNULAR NEBULÆ. They are scarce objects in the heavens, amounting to only about half a dozen; and among the annular nebulæ must be reckoned the sidereal system to which our own solar system belongs. It consists of a ring of stars, closely crowded together, called the Milky Way, and a disk-like stratum of stars less closely arranged, which disk entirely fills up the space within the Milky Way. One of the annular nebulæ has been compared to a gauze stretched over a hoop. Our own stellar system is the same. The Milky Way is the hoop; and the stars of the interior disk, more sparsely scattered, are the gauze. In the original formation of our sidereal system, all the matter was not thrown off as a ring: some was left for the interior disk; and this was probably the case with all annular nebulæ, whether we be able to see the disk or not.

18. When the nebulous matter of our interior disk separated by contraction into secondary nebulæ, and formed solar systems, some of these solar systems became very large. The clusters known as Præsepe and Coma Berenicis contain thousands of suns like our own. The Pleiades and the Southern Cross each contain about one hundred and fifty bright stars. From these larger solar systems the number of suns in others dwindle down to four, three, and two; but the vast majority have only a single sun. Those with

only four, three, or two are called quadruple, triple, and double stars, because the two, three, or four, appear to the naked eye as but a single bright star. When the nebulous matter, either of a primary or secondary nebula, was spread out by rotation and centrifugal force in a disk composed of closely crowded rings, then when contraction occurred there was no certain rule into how many fragments any disk should break. If there happened to be two spots more dense than the rest, then the entire disk might be attracted around them. Thus two new centres of revolution would be established, and both these new centres would revolve around the original centre of gravity. If the materials around these new centres were small, they would form a double star; if they were enormously large, as in the primary nebulæ, they would form two large closely connected sidereal systems, each one revolving around its own centre, and both together would revolve around their original centre of gravity. When seen from our distance, they are called DOUBLE NEBULÆ. Dynamical laws must operate in the same manner whether on a small or a large scale; and hence the process of creating double stars and double nebulæ is the same. The double stars may each have a hundred or two hundred planets and satellites revolving around them; as our own sun has probably more than two or three hundred attendants, counting the asteroids and comets of short period. But each of the centres of a double nebula may be surrounded by millions of suns.

19. Some of the large solar systems, composed of hundreds of suns, seem to have changed from a disk-like to a *globular* form. This may have happened from that action of gravity called perturbation. In our own solar system some of the asteroids, being near together, have been so greatly affected by their mutual gravitations as to be thrown thirty degrees out of their original orbital planes. When the clusters are very large, and the stars are crowded nearly together, there is no reason why the changes should be limited to thirty degrees. These changes may occur on both sides of the original orbital plane, and thus form a system so nearly globular as to appear such at our distance.

20. While solar systems generally have central suns, *the sidereal systems very rarely have a large central body.* In the primary nebulæ, forming sidereal systems, rotation began chiefly by the falling together of neighboring nebulæ, and this generally produced rotation at once all the way from the circumference to the centre. Being very large, many millions of times larger than the secondary

nebulæ, their materials had by contraction a long distance to fall in the rotary way towards the centre. Hence all their materials could acquire a velocity so great that the centrifugal could equal the centripetal force. Therefore none of the materials could settle to the centre to form a central sun. But the secondary nebulæ were held firmly in their orbits by the equipoise of centripetal and centrifugal force. They could, therefore, seldom fall obliquely into one another to produce a rotation through all their interiors. Being incomparably smaller than the primary nebulæ, they had but a short distance to contract and fall by rotation to the centre. Hence they could not gain a high velocity, nor a centrifugal force strong enough to keep the greater part of their materials from subsiding to the centre. None of them formed solar systems resembling annular or planetary nebulæ. A few resemble elliptical nebulæ; and the great mass of them are like the sidereal systems called nebulous stars, — the halo of planets and satellites around the single sun, in a solar system, being exactly analogous to the haze of millions of smaller suns around the great central sun in a sidereal system.

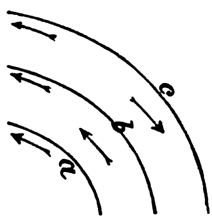
21. The primary nebulæ were all stationary in space. They rotated on their axes, but moved not from their positions. There was nothing to make them move. Gravity could bring together the first irregular clouds which were within each other's spheres of attraction, but this falling together could produce rotation only, and not a movement of translation from place to place. *Therefore the sidereal systems resulting from the primary nebulæ are now stationary.* But all secondary nebulæ, from their first existence, were in rapid motion. They were formed of broken rings which swiftly revolved around the centres of their parent primary nebulæ. Therefore, the solar systems, resulting from the secondary nebulæ, move with great velocities in their orbits. The same may be said of tertiary nebulæ and their resulting planetary systems.

22. From this immobility of sidereal systems, we must conclude that there is *no central sun of the universe*, — no one special metropolitan point, around which all systems of stars revolve. Moreover a centre is a point equally distant every way from some boundary. But the universe has no bounds; therefore it has no centre, and no central sun.

23. From this difference between the primary and secondary nebulæ, in point of motion, we find *two differences in the origin of their rotations.* The exterior side of a secondary was the one

turned away from the centre of its sidereal system; the interior side was the one toward that centre. The exterior side moved more rapidly, and the interior more slowly, than the centre of the secondary nebulæ. This difference of movement, as the nebulæ continued to contract, must have led to *direct* rotation.

The secondary nebulæ were flying past one another, and through gravity were raising tidal waves on each other's surfaces. The nebulæ *a*, *b*, and *c*, in the figure, move in their orbits in the direction of the orbital arrows: *a* moves faster, and *c* slower than *b*. Hence conjointly they would raise around *b* tidal waves in the direction of the arrows at *b*. These tidal waves would lead to *retrograde* rotation.



These two sources of rotation were possessed by the secondary nebulæ, in addition to the two possessed by the primary nebulæ: which latter were, first, their falling together; and, secondly, their assumption of round forms. Gravity, however, was the operating force in all four cases. The most effective by far was that of the falling together of the primary nebulæ. The falling together of the material of a ring of a primary nebula, forming a secondary nebula, was but slightly effective in producing rotation, because that material had to travel nearly along the line of the orbit, and hence the different portions could not strike one another obliquely. Among the four causes affecting the secondary and tertiary nebulæ, the most powerful in producing rotation was the difference of velocity between their exterior and their interior sides. Hence the planets and satellites of our solar system have nearly all a direct rotation. But in the conflict of the four different causes it is not to be wondered at that retrograde rotation was produced in one or perhaps two planets of our system. There may have been also another cause for retrograde rotation, and acting through gravity, as has been shown in "The Origin of the Stars." It has there also been shown that from the same cause the orbital planes of planets and satellites may be removed from the equatorial planes of the bodies around which they revolve. Gravity has also there been pointed out to have been the cause which changed the orbits of the celestial bodies from their original rings in circles to ellipses.

24. It has now been proved, that gravity acting on slowly condensing nebulous matter has moulded it into stars, and arranged them in great sidereal systems called nebulæ, various in their forms,

as annular nebulæ, planetary nebulæ, elliptical nebulæ, double nebulæ, and nebulous stars. We have also seen how the action of gravity accounts for the formation of solar systems; some with a central sun like our own, and others consisting of large, nearly globular clusters of stars; multiple stars, triple stars, and double stars. The action of gravity also accounts for the occasional retrograde rotation of the stars, for their elliptical orbits, and for the departure of these orbits from the equatorial planes of their controlling central bodies. What seem to be irregular nebulæ may, in reality, be regular. The apparent forms of all irregular nebulæ change surprisingly by the aid of higher telescopic powers, and their ultimate symmetrical forms may not yet be reached. Sometimes two or three regular nebulæ may be seen one beyond another, and the whole may appear to us like a single irregular nebula. Many stars we know have lost their luminosity, and this loss in some nebulæ may give them a torn and irregular appearance. While our solar system may be accounted for by the action of gravity, the planets may nevertheless be arranged around the sun in no symmetrical order; and in like manner all the stars of a sidereal system may revolve around their common centre of gravity, but they may maintain no positions with respect to one another which would give the whole a regular appearance, especially at a long distance. Therefore, while we behold in the heavens many forms of sidereal systems which harmonize beautifully with the action of gravity, we cannot say that really there are any forms which may not have been produced by that action.

25. Among the many systems of stars, whatever be their sizes or their forms, there is a wonderful unity of structure. This unity flowed from their common origin by rotation and the abandonment of rings. The rings of Saturn are believed, from sound reasons, to be composed of meteorites, small stones, from the size of a pebble to a few inches, or a few feet or yards, in diameter. The ring of the asteroids is composed of similar small bodies, some of the larger reaching the diameter of a few miles. If the asteroids already discovered were arranged around in a ring at equal intervals, we would see them at distances apart of about five diameters of the moon. Soon these distances will be much less on account of their rapid rate of discovery. In the Milky Way the stars are so closely crowded that, to the naked eye, the ring appears unbroken. These three rings are one in a planetary system, one in a solar system, and one in a sidereal system. But whatever be

the system, or whatever the size, it is a matter of mathematical demonstration that they may have flowed from slowly condensing nebulous matter rounded and rotated by gravity. Light crosses the diameter of the rings of Saturn in about a second of time. It crosses the ring of the asteroids in about an hour. It crosses the ring of the Milky Way in about five thousand years. The forces by which the universe has been created operate in precisely the same manner, whether on a large or a small scale. The crystals of some minerals measure occasionally a foot in diameter, and often they are so small as to be invisible to the naked eye. But the microscope reveals their angles, their edges, and their planes to be shaped and proportioned, whether small or great, in exactly the same way. This identity of structure flows from identity of creative force. The stars occupying the space within the ring of the Milky Way are situated in a stratum or round disk, and this disk must be regarded as formed originally from a series of rings closely arranged one within another. We find the same arrangement in the far distant sidereal systems. The annular nebulæ are but repetitions of the Milky Way. The planetary nebulæ are repetitions of our own interior disk-like structure of stars. An elliptical nebula is the same, except that the rings and their resulting stars were crowded more thickly toward the centre. A nebulous star is again the same with this difference, that it did not throw off all its material in the form of rings; a considerable portion subsided in the centre as a great controlling sun in the system. And here we come to a form like our own solar system, the only difference being that our sun, while much smaller, has also a smaller number of revolving attendants. And what are the planetary systems of Jupiter, Saturn, and Uranus, but repetitions of the solar systems and of nebulous stars? We have already seen how double stars and double nebulæ are but different degrees of the same structure, and different illustrations of the effects of gravity, when rounding and rotating the various nebulous masses. These masses, differing in size, in shape, in density, and in situation, have left each one its own peculiar impress on the finished work of gravity.

26. Our solar system has within itself more than four hundred different and independent motions. The twenty moons or satellites have each four motions: one of rotation on their axes, another around the planets, a third around the sun, and a fourth along the unknown orbit of the sun around the centre of gravity of our

sidereal system. The eight planets, the one hundred asteroids, and the three rings of Saturn have each three motions, and the sun has two. When we contemplate our solar system with this mazy complication of more than four hundred different movements, and then inquire what is the force which originally imparted all these velocities, approaching the very nearest to lightning speed, we evidently have before us one of the most difficult problems that the human mind has ever encountered. Newton declared, "It is not to be conceived that mere mechanical causes, such as gravity, could give birth to so many regular motions." "These bodies may indeed persevere in their orbits by the mere laws of gravity, yet they could by no means have first derived the regular positions of the orbits themselves from those laws." When Newton made this a part of his *Principia* nothing could seem more likely to be true. The complexity of more than four hundred movements in a mazy dance, one within another, seems indeed beyond the reach of any one force. Hence his assertion has often been repeated by learned men, on both sides of the Atlantic, from his day down to our own. But now the grand truth breaks on our minds, with all the clearness of the sun, that gravity is really the force which gave birth to this intricate complication of so many motions in one harmonious system. After the announcement of the Copernican theory, one hundred and thirty years passed on, and Newton discovered that gravity is the indispensable force on which that theory is founded. After the discovery of Newton one hundred and ten more years passed away, and Laplace announced the nebular theory, accounting for the origin of the solar system; and since this announcement of Laplace, another seventy years have intervened, and now the discovery has been made that gravity is also the foundation of the nebular theory. So slow is the growth of human intelligence. Both the Copernican theory and the nebular theory are alike impossible without the action of gravity. By the one theory gravity now holds all the stars in their orbits; by the other theory gravity originally gave all the stars their motions in those orbits. We can now tell the order of time in which the satellites of our system received each one their four several independent motions. The first was the motion along the unknown orbit of the sun around the centre of gravity of our sidereal system; the second was the motion around the sun; the third was the motion around the planets; the fourth and last was the motion around their own axes.

But we are astonished, not merely at the coincidence between the action of gravity and the harmony of these four hundred independent movements in their complicated *directions*. In addition to this, there stands before us the wonder of the coincidence between the *velocities* of these four hundred motions, — no two being equally rapid, — and their calculated velocities as due to gravity. I have elsewhere shown mathematically that all the planets and satellites of our system have precisely such velocities as are due to gravity, wanting only a small amount due to friction. In the contraction of the nebulous sun the velocity of rotation coincided so nearly with the velocity due to gravity, that only one per cent. was lost by friction in a contraction of 250,000,000 miles in diameter.* This friction was an absolute necessity, because the rotating exterior was moving over the unrotating or slowly rotating interior.

I need say nothing to prove that the discovery of the projectile or centrifugal force in astronomy is quite as important as the discovery of the centripetal force, whether we look at its bearings on science, or on the moral and religious advancement of mankind. As the discovery of the centripetal force proved the Copernican theory to be true, and placed it on an immovable basis, so the discovery of the centrifugal force proves the nebular theory to be true, and places it on an eternal foundation never more to be shaken. Hitherto, in the history of creation, we have been able to go back by the teachings of geology to the period when our globe was all covered with water, no dry land anywhere appearing. Beyond that ancient period all was doubt or unverified conjecture. Now we can go back to the time when all matter was evenly diffused through all space as a thin vapor, millions of times more rare than hydrogen. In writing the doings of the great Creator we can make that far distant era our starting point, and from there we can come down with a firm and an assured tread through all the long tracts of time to our own day.

* See "The Origin of the Stars," section 18th.

4. THE VELOCITY OF NEBULAR ROTATION. By JACOB ENNIS, of Philadelphia, Penn.

I HAVE been the first and the only one to demonstrate both the velocity of nebular rotation, and the force which causes that velocity. Nevertheless there are others who profess to have done both these things. The object of the following pages is to show that their professions are without foundation.

I. THE VELOCITY OF NEBULAR ROTATION.

The late J. P. Nichol, Professor of Astronomy in the University of Glasgow, writing on the nebular theory, in his "Architecture of the Heavens," letter 7th, says: "The nebular theory must yield a law accounting for the relation of the velocity of each planet to its distance; it must show that the velocities or times of the revolution of the several planets are consistent with the account given of their origin. Now the inquiry which contains the reply to this query is not difficult, and has lately been taken up and completed by a young French geometer. The velocities of the several planets should clearly coincide with the period occupied by the sun in rotating on its axis *at the time when his atmosphere extended to their present orbits*. Now the times necessarily occupied by the sun in rotating in those earlier states are *calculable;* and we find the most singular coincidence of theory with observation. Each planet revolves at present nearly in the time in which he must have rotated when the corresponding outer zone of his atmosphere was abandoned,—a circumstance which M. Comte considers as bestowing almost demonstrative evidence on the Nebular Cosmogony.".

The very intelligent author of "The Vestiges of Creation" lays great stress on the same point in these terms: "M. Comte, of Paris, has made some approach to the verification of the hypothesis, by calculating what ought to have been the rotation of the solar mass at the successive times when its surface extended to the various planetary orbits. He ascertained that *the rotation corresponded in every case with the actual sidereal revolution of the planets, and the rotation of the primary planets in like manner corresponded with the orbital periods of the secondaries.*"

M. Comte himself, in his "Cours de Philosophie Positif," says: "From the whole of these comparisons I deduced the follow-

ing result: — supposing the mathematical limit of the solar atmosphere successively extended to the regions where the different planets are found, the duration of the sun's rotation was, at each of these epochs, sensibly equal to that of the actual sidereal revolutions of the corresponding planet; and the same is true for each planetary atmosphere in relation to the different satellites."

These calculations of Comte are not what we would suppose them to be from the several descriptions. They do not begin with the first very slow rotation of our nebulous sun, and show *how and why* that rotation must of necessity increase during the progress of contraction, and from time to time equal all the planetary velocities. On the contrary, M. Comte merely compared the centrifugal and centripetal forces at the equatorial surface of our nebulous sun when it was expanded to the orbits of the several planets. He found that in the nebulous sun then, as in the planets now, these two forces would be equal at those distances and with those velocities. But this is merely a truism. If it be true of the present planets, it must have been true of the nebulous sun's equatorial surface, providing the distances and the velocities were the same in both cases. Because with the same distance and velocity, the centrifugal force must for ever remain the same; and, again, at the same distance from the centre of the sun, gravity or the centripetal force cannot vary. But this is not the problem which we demand. We demand to know *how or why* the nebulous sun received those velocities at the several planetary orbits, so that the centrifugal and centripetal forces might be equal. This is what I have shown, and this is the solving of a problem entirely different from that of Comte, which has been so often quoted.

But in truth Comte did not find this exact equality between these two forces, but only an approximation. And when he made the two forces equal, he found a difference between the time of the planetary revolution and the time of the solar rotation. He says: "It is remarkable that this difference, though increasing as the planet is more distant, preserves very nearly the same relation to the corresponding periodic time, of which it commonly forms the forty-fifth part." Prof. Nichol says: "This difference, so far from overthrowing the presumption arising from the close correspondence, only opens more engrossing questions. The difference between the two periods must have originated in some laws and definite actions, although they are yet unknown. Future analysis will unquestionably detect these laws." Several years ago, in look-

ing over this matter, I "detected these laws." The discrepancy results from the former erroneous determination of the earth's distance from the sun. The earth's distance determines the distances of all the other planets. Recently our earth's distance has been ascertained to be about 3,000,000 miles shorter. This makes the distance of Neptune about 100,000,000 miles shorter. The former erroneous distance caused an astonishing discrepancy between the centrifugal and the centripetal forces; or between the times of revolution of the planets and the nebulous solar rotation, if we assume the two forces to be the same. I have spoken of this in "The Origin of the Stars," pp. 237–8. The planets have been assumed to be further distant than was the surface of the nebulous sun when they were parted as rings. Comte says this discrepancy in their periods of revolution becomes greater and greater as we pass to the more distant planets. This I also found; and it is because the erronéous distance of the earth becomes repeated so much oftener in the cases of the more distant planets: in Neptune, whose distance is thirty times that of the earth, it becomes the most glaring of all.

E. Loomis, LL.D., Professor of Astronomy in Yale College, gives a statement of his own on the velocity of nebular rotation. It is contained in his "Elements of Astronomy," published in 1869. The title and tenor of his 448th section is as follows: —

"How the Nebular Hypothesis may be tested. This hypothesis may be tested in the following manner. The time of revolution of each of the planets ought to be equal to the time of rotation of the solar mass at the period when its surface extended to the given planet. Let us then suppose the sun's mass to be expanded until its surface extends to the orbit of Mercury. If we compute the time of rotation of this expanded solar mass, we shall find it to be nearly four months, which corresponds with the time of revolution of Mercury. If we suppose the sun's mass to be farther expanded until its surface extends to each of the planets in succession, we shall find by computation that the time of rotation of the expanded solar mass is very nearly equal to the actual time of revolution of the corresponding planet.

"So, also, if we suppose the earth to be expanded until its surface extends to the moon, we shall find by computation that its time of rotation corresponds nearly with the time of the revolution of the moon. In like manner, if we suppose each of the primary planets to be expanded until its surface extends to each of its satellites in succession, we shall find that its computed time of rotation is very nearly equal to the actual time of revolution of the corresponding satellite."

This statement of Prof. Loomis contains a new condition added to those of Comte, Nichol, and the author of the "Vestiges of Creation;" still it has the *appearance* of being the same, and I suppose he thought it was the same. He says, "Let us suppose the sun's mass to be expanded until its surface extends to the orbit of Mercury, then we shall find by computation its time of rotation equal to a revolution of that planet, and so on corresponding successively to all the other planets." But, in reality, we shall find a vastly different velocity. Instead of 110,000 miles per hour, the velocity of Mercury, the time of the sun's rotation at his orbit would be less than fifty-six miles per hour. At our earth's orbit, instead of being 68,000 miles per hour, it would be less than twenty-two miles per hour. At the orbit of Neptune, instead of being 12,500 miles per hour, it would be less than *one* mile per hour. These numbers of mine result from the principle of the conservation of areas; they are found with sufficient nearness in this way. The sun's *radius vector* — the line from his centre to his equatorial surface — must sweep over equal areas in equal times. That radius is now 441,000 miles; his rotation velocity per hour is 4,500 miles; therefore the area swept over per hour in miles is very nearly $441{,}000 \times 4{,}500 \div 2$. When expanded to the orbit of Mercury these numbers, to yield an equal area, must be Mercury's distance, $35{,}550{,}000 \times 56 \div 2$ very nearly. When expanded to the earth's orbit the numbers must stand,— earth's distance $92{,}000{,}000 \times 22 \div 2$ nearly. When expanded to Neptune these velocity numbers, fifty-six and twenty-two, dwindle down to less than one.

The error of Prof. Loomis's statement is seen at a glance when we compare the sun's velocity of rotation, now 4,500 miles per hour, and his velocity when expanded to the orbit of Mercury. Then it must have been equal to Mercury's present velocity, which is 110,000 miles per hour. How in the process of expansion can this increase of velocity be obtained? By no known means. *Expansion would produce a much less, instead of a much greater velocity.* The same difficulty opposes the statements of Comte and of all others, until my own. If the sun rotated with a velocity of 110,000 miles per hour when expanded at the orbit of Mercury, then it should increase, and not lessen its velocity to 4,500 miles per hour, when contracting to its present dimensions; the same as it increased its velocity at the orbit of any planet when contracting all the way from Neptune to Mercury. Why did not the sun keep on regularly as before increasing its velocity inside the orbit of

Mercury? All writers on the nebular theory, both friends and foes, before myself, overlooked this difficulty. No one ever conjectured the cause until it was published by myself in "The Origin of the Stars," section twenty-two.

The same difficulty occurs also, though in a lesser degree, outside the orbit of Mercury all the way to Neptune. In the course of contraction the *radius vector* of the nebulous sun, instead of sweeping over equal areas in equal times, swept in fact over smaller and smaller areas at the distance of every succeeding planet. This would have stood as a valid objection to the nebular theory. But happily I discovered that nebular rotation must necessarily begin, in nearly all cases, not at the centre of the nebula, as all previous writers had supposed, but on the surface. This surface rotation must of necessity be *retarded* by friction on the unrotating interior; hence the *radius vector* must sweep over smaller and smaller areas in proportion to the amount of *retardation*. But in a general sense the principle of equal areas in equal times holds true; because what is lost in velocity by the particles on the exterior is gained by those of the interior. The *sum* of the areas swept by the *radii vectores* of all the particles must be a constant quantity; but practically these areas cannot be computed, because we do not know the densities of the several strata of the nebula, and hence we do not know the positions of the particles, or the lengths of their *radii vectores*. Nevertheless on Prof. Loomis's plan, and what *appears* to be the plan of Comte, Nichol, and others, the principle of equal areas in equal times must be followed out with a single *radius vector* extending from the sun's centre to his surface; and then the absurdity of their statements soon becomes manifest.

Nothing but the principle of *retardation* can explain the apparently discordant velocities necessary in the nebular theory, and according to my calculations this retardation comes in, not at last as a mere makeshift, but in the very beginning as an unavoidable condition in nebular rotation.

II. The Cause of the Increasing Velocity in Nebular Rotation.

The reason why all previous writers were unable to calculate the increasing velocity of nebular rotation was because they had not discovered the cause of that rotation, or of its increasing velocity. But a cause they nevertheless assigned, and I am now to show that their cause was not the true one.

Nichol, in his seventh letter in the "Architecture of the Heavens," says: "The condensation of a diffused and a comparatively slow whirlpool cannot take place without a great and growing increase in the velocity of its rotation, inasmuch as the momentum or amount of rotatory force must, in all its stages and conditions, continue the same." Here "the increase in the velocity of rotation" is ascribed to "the momentum of rotatory force." This, indeed, when once imparted, from whatever cause, might produce an increase in angular velocity; but an increase in linear velocity is necessary. Hence all the planets, beginning with Neptune and coming down to Mercury, have, in each case, a greater and greater linear velocity, — Neptune 12,500 miles per hour, the Earth, 68,000, and Mercury, 110,000. But mere "momentum" or "inertia" cannot increase its own linear velocity. It can increase only its angular velocity, if transferred nearer the centre of rotation. But an increase of angular velocity, with no increase of linear velocity, will not give a centrifugal force equal to the centripetal force at a nearer distance toward the sun's centre. The equality of those two forces are necessary to separate a nebulous ring and form a new planet or satellite.

Stephen Alexander, LL.D., Professor of Astronomy in Princeton College, N. J., in his elaborate essay on the nebular theory, in "Gould's Astronomical Journal," Vol. II., says: "By a contraction from loss of heat there would result an increase in angular velocity of rotation, the *momentum* remaining unchanged." This is the same doctrine as that of Nichol; momentum, no matter how acquired, is the cause of an increase of angular velocity of rotation. Not a word is said of an increase of linear velocity, which is absolutely necessary.

The late Professor Sears C. Walker, while discussing the nebular theory in the "Proceedings of the American Association for the Advancement of Science," second meeting, p. 218, says: "If a planet in a primitive state existed in the form of a ring, revolving around the sun, the *momentum* of *rotation* must, by virtue of the principle of conservation of movement, have existed in some form in the ring." This is plainly the same doctrine as that of Alexander and Nichol, and needs no additional remarks.

Robert Grant, F. R. A. S., in his "History of Physical Astronomy," p. 162, says: "Now it follows immediately from a well-known principle in mechanical science, that when a body is endued with a rotatory motion, and not exposed to the action of any extraneous forces, the principal moment of inertia, or, in other words, the sum of

the products formed by multiplying each particle into its angular velocity and the square of its distance from the axis of rotation, is a constant quantity. The number of particles then remaining the same, if their distances from the axis of rotation be diminished, their angular velocities must be increased, and *vice versa*."

Whatever be the reason for the truth of the above proposition, involving "the angular velocities," and "the squares of the distances," it is manifest that Grant assumes as the reason, that the original "moment of inertia is a constant quantity." His view, therefore, respecting the *cause* of increasing rotation velocity, is the same precisely as that of Nichol, Alexander, and Walker. He wrote the above not of a contracting nebula, but of our present earth contracting from loss of heat. But the reason for both must be the same. Nothing in his statement shows him to be aware that an increase in linear, as well as in angular, velocity would be the result of contraction, and that gravity would be the cause of that increase. I have quoted his language merely to show how even learned men may not understand the reasons for a mathematical formula, and yet may be able to work correctly by such formula.

I have now finished what I proposed to say of the followers of Laplace in their advocacy of the nebular theory. A very few words are necessary about the great master himself. All that he wrote, that I am aware, of the nebular theory, I have carefully copied in Appendix V. of "The Origin of the Stars." On p. 381–2 he speaks of the conservation of areas, but derives no benefit from the application of that doctrine to his grand theory, except that in the contraction of the sun there must be an increase of velocity of rotation, whether angular or linear he does not say, and perhaps he did not think. But he did not prove, what is absolutely essential to prove, how this velocity of rotation could become great enough to afford a centrifugal equal to the centripetal force. He saw well enough that these two forces must be equal for the abandonment of an equatorial ring; but how to make them equal by simple contraction, or whether that was really possible, he did not show. Hence after announcing his splendid theory, one of the very grandest achievements of the human mind, he closes with these rather melancholy words: "This origin of the arrangements of the planetary system I offer with that distrust which every thing ought to inspire which is not the result of observation or *calculation*." In this condition the nebular theory lay for about seventy years, and of this Professor D. Kirkwood, LL.D., of the

University of Indiana, is one of the best judges. In "Silliman's Journal," Vol. XXX., p. 161, his language is as follows: "Cogent arguments, it is true, were adduced by Laplace and Pontecoulant in favor of the nebular hypothesis, but very little has since been accomplished tending either to invalidate or confirm it."

My own discoveries have at length placed the nebular theory on a firm mathematical foundation. The chief of them are these: 1st. That gravity must necessarily and unavoidably produce rotation as well as rotundity in all nebulæ. 2d. That gravity may increase that rotation so rapidly as to afford a centrifugal equal to the centripetal force. 3d. That in nearly all nebulæ forming solar and planetary systems, rotation must begin on the surface, and hence must be *retarded* by the unrotating or slowly rotating interior. This retardation accounts for a vast number of most important stellar phenomena. Nothing in my calculations opposes the doctrine of equal areas swept by the *radius vector* in equal times. If the nebula forming our solar system, and extending at first half way to the nearest fixed star, had originally a rotation velocity of only the one-third of a mile per hour, then its *radius vector* would have swept over an area equal to that of Mercury, whose orbital velocity is 110,000 miles per hour.

In speaking above of Laplace I should have added that he not only said nothing about the precise velocity of nebular rotation, but he gave no cause whatever for the origin of that rotation.

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5. Cosmogony. By L. Bradley, of Jersey City, N. J.

The nebular hypothesis of creation, as suggested by Laplace, has, with some modifications, been a favorite theory with me for many years, and one by which I have been able to account for the phenomena of nature more satisfactorily to my own mind than by any other. This theory, as I accept it, implies the assumption of certain fundamental truths and laws, which have been well established by modern science, and have ceased to be hypotheses; viz.:

Matter and Force

are everlasting and indestructible. There is no annihilation or new creation. The question whether there are ultimate, indivisi-

ble *atoms*, or whether matter is infinitely attenuable, is as yet unsettled. Mayer says: "We do not know whether atoms exist. An *atom* cannot be made an object of our investigation."

ETHER

pervades and fills all space, and the interstices of all ponderable matter. It is an inscrutable, mysterious principle; a spirit or an entity, *in*, *by*, or *from* which is developed all *force;* all the phenomena of NATURE: gravitation, heat, light, electricity, polarity, magnetism, chemical affinity, vitality, mechanical action,—in short, all kinds of energy, force, or motion. All the apparently distinct forces are affections of matter, and are convertible one into another: there is perfect correlation among them. A force exerted in one form at this moment may, in a day or a minute, be observed in one, two, or ten other modes of force; or it may be stored up and *conserved* for future development and future use.

According to Dr. Faraday, a single drop of water contains chemical relation sufficient to develop a powerful flash of lightning. A single pound of coal contains a conservation of force sufficient to raise many tons a foot in height. To be more exact, Rumford has demonstrated that the perfect combustion of one pound of carbon develops the force of 11,120,000 foot-pounds.

Every force has its correlative counter force. Every positive has its negative. Action and reaction are absolutely equal throughout all nature.

All the modifications of force consist in varied forms of undulation of ether, or of matter, somewhat as sound consists in undulation of matter.

If this theory be true as to light, heat, and electricity, which is now well established, why not as to all the other affections of matter into which, and from which, they are all convertible?

All matter is susceptible of three modes of existence,—the solid, the liquid, and the gaseous or *nebulous*,—and the several transformations are effected by heat and cold. Only 180° Fahr. are sufficient to resolve solid water into nebula; 702°, mercury; solid zinc fuses at 773°, and evaporates at less than 1000°. A few thousand degrees are sufficient to resolve all the component matters of the earth's crust into nebula. I have entertained the hypothesis that matter may be resolved into a *fourth* state, infinitely attenuated and constituting the *universal ether*. This must preclude the notion of ultimate atoms, and must suppose an extended attenua-

tion of the individual molecules of nebula, and that in this state they become a homogeneous, and an almost non-resisting medium. A plausible argument in favor of this is based upon the fact that no physicist has ever yet been able to produce a perfect vacuum; in the Torricellian vacuum, at the top of the barometer, the space is filled with the vapor of mercury. The tendency of all matter to attenuate when all pressure is removed is well known. Why may not this, then, constitute the *rationale* of the *Universal Ether*, and admit the supposition that all space is filled with matter in some form?

The telescope brings to our view matter in every visible state,— the highly attenuated nebula, nucleated nebula, and the perfect star.

THE SOLAR SYSTEM WAS ONCE A NEBULA.

How came it so?

By the patient and indefatigable researches of Herschel, Struve, Peters, Maedler, and others (Bessel having first led the way), we are invested with the knowledge that the sun, in company with the other masses of the Milky Way, are all in motion, and that they are all moving in nearly the same direction.

Combining the profound researches of Argelander, Struve, and Peters, we are now able to pronounce the following wonderful results:—

The sun, attended by his planets, satellites, and comets, is sweeping through space, towards the star π, in the constellation of Hercules, with a velocity of 33,350,000 miles per annum. It is further demonstrated that we are all in the course of a great astral revolution, the centre of which M. Maedler has shown to be in the bright star Alcyone, near the centre of the beautiful little cluster, the Pleiades. This fact has been confirmed by others.

To give some idea of the vastness of the scale on which this great structure is erected, I will give a few figures:—

The star π, in Hercules, being a star of the third magnitude, is at such a distance from us, that its light in coming at the rate of 12,000,000 miles per minute requires forty-five years. It will take then 8,516,294 years for the sun to reach the point in space where that star now resides.

Light to come from Alcyone at the great astral centre, which is a star of the fourth magnitude, requires about sixty-five years,— 34,187,400 minutes. This multiplied by 12,000,000, the distance

which light travels per minute, gives 410,248,800,000,000 of miles, and this divided by 33,350,000, the distance passed over by the sun in a year, gives 12,301,000 years for the sun to move that distance; and this is only the *radius vector* of the great orbit of the sun, which we may multiply by six for the time required to perform a single revolution, which is 73,806,000 of years. Should it be demonstrated, however, that this great orbit is a very eccentric one, and that the sun is now in aphelion, or more properly *aphalcyon*, and moving at a slow rate of speed, then the estimated time of revolution would be much reduced, — say to 30,000,000 years. Even these figures are enough to astound the imagination. But we must lay aside our childish modes of thinking, and learn to view Nature as she is, in both the *infinite* and the *infinitesimal*. How strangely the foregoing figures contrast with the following: In bringing the microscope to our aid, it is said that a single grain of the polishing powder *tripoli* presents to our astonished view 2,000,000 of the skeletons of once living beings, and that each filament of the spider's web, of which it would take 36,000 to make the thickness of a thread of common sewing silk, is composed of 6,000 finer filaments which were secreted by 6,000 perfect glands.

I ask now, would it not be reasonable to suppose that the sun might, somewhere in the course of his great astral round, find himself in a region of cold, *a great astral winter*, where all would be chilled and congealed; and then, in the course of a few millions of years, reach a climate more mild, *a great astral summer*, in which a temperature many degrees higher than that required here to gasify all matter might be found, and where all would again be resolved into nebula?

Is not this in harmony with Nature's laws as we see them displayed everywhere?

When I commenced to write this paper, I supposed that I was the first to conceive this idea of an astral winter and summer, but I have since found in an essay on heat by Grove, a paragraph in which he says: "It is quite conceivable that the whole solar system may pass through portions of space having different temperatures, as was suggested, I believe, by Poisson; that, as we have a terrestrial summer and winter, so there may be a solar or systematic summer and winter, in which case the heat lost during the latter period might be restored during the former."

I do not grieve at my privation of the honor of being the first to conceive so grand an idea; but am rather pleased to know that I was inspired to think as great men had thought.

This great astral summer having resolved our sun and his attendant planets, satellites, and comets into a nebula, let us trace the operation of the well-known laws and forces by which he would be restored to his present condition.

To be rational, an hypothesis in physical science can admit nothing supernatural: all the phenomena pertaining to it must be in harmony with itself, and with *Nature's laws*, the laws of the great first cause, — GOD.

As the Nebular Theory is understood by some, it is taught that all the matter of the universe was once in a nebulous condition, infinitely attenuated, and uniformly diffused throughout infinite space. I do not so accept the theory. It appears to me that there would not be heat enough to maintain all matter in a condition so attenuated; or if there were, whence could the heat radiate, so as to admit of contraction by gravity, and where would be the centre of gravity, or many centres, as we see now?

I prefer to assume that

MOTION

is a principle as universal and eternal as *matter* and *force;* that it always has been, as we now see it, the universal order of Nature.

Grove says, and I think truly: "Of absolute rest Nature gives us no evidence. All matter, as far as we can ascertain, is ever in motion, not merely in masses, as with the planets and spheres, but also molecularly, or throughout its most intimate structure; thus every alteration of temperature produces a molecular change throughout the whole substance, heated or cooled."

All matter, both organic and inorganic, is moving in obedience to and under control of a most beautiful and harmonious code. All is changing, revolving, disappearing, and reappearing in the most fanciful order, and such, I think, has been the rule of things from eternity. The matter of the solar system has alternated between nebula and solid, perhaps, millions of times, and all the visible stars and nebulæ have, each in its turn, done the same; but they were never all in the same condition at one and the same time.

The question now arises, Whence the extreme heat and intense cold of those great summers and winters?

If our hypothesis of a fourth state, or mode of aggregation of matter, and of its infinite attenuation, constituting the Universal Ether, be admitted, it follows that ether itself, like matter in the solid, liquid, or gaseous state, is subject to the law of universal

gravitation, and is, therefore, ponderable in proportion to its density, and its density must be inversely proportional to its distance from surrounding centres of gravity; and yet its density at all points must be such as to entirely fill the interstellar spaces.

Ether, then, is an elastic fluid,—a positive, substantial *entity*,—and, as Tyndall properly says, "it makes the universe a whole, and renders the intercommunication between star and star possible."

Admitting the *wave theory* of light and heat as we now do, we are struck with astonishment in contemplating the amount of heat force propagated by the undulation of ether from the sun to the earth,—a force sufficient to evaporate, and to elevate to the mean height of the clouds from the ocean, more than 2,000,000,000 tons of water in every minute of time.

If the heavenly bodies are thus floating in ether, and if the ether is more or less dense, according as the number of bodies floating in it, in a given space, is greater or less, it would scarcely seem to require argument to convince one that if the mass constituting the solar system were, in the course of its revolution, to pass from a region of great rarity and intense cold, and plunge with accelerated velocity into a region of great ethereal density, where great numbers of heavenly bodies are clustering in close proximity, and, perhaps, in a nebulous state, the impact alone would be sufficient to gasify and convert it into nebula, thus producing a great summer.

We are not without evidence of the effect of impact under circumstances quite similar. Witness the meteor which we may see on any clear night: at first, a solid substance, but, on coming into our atmosphere, in a region high up, of extreme rarity and intense cold, it is first heated to flame, then gasified, and finally dissipated. Pressure by impact is probably, therefore, one important source of the heat incident to a great summer. How many and what others there may be, we do not know.

Now let us suppose our solar nebula, of some 10,000,000,000 of miles in diameter (this is probably not more than the truth, for the orbit of Neptune is near 7,000,000,000), balanced in space, just at the point of maximum heat where the contracting force of *gravitation* and the expansive force of *heat* are balanced. We may now suppose its mass, in itself, to be in a state of quiescence; the heat which it radiates, and that which it receives, are equal; it is neither contracting nor expanding. But such a state can continue only for an instant; the mass is moving in its orbit, and passing into a colder region; it is now radiating faster than it receives;

gravitation is free to act, and the mass is contracting and falling toward a common centre.

What may we now expect to see? What do we see when a fluid, either elastic or non-elastic, is gathering toward a common centre? What do we see in the common funnel when we fill it with liquid, and let the liquid flow through it?

Rotation?

Not necessarily so; but the chances are vastly in favor of rotation, and when once commenced rotation increases with accelerating force.

The effect of rotation is to incline matter to separate and go off in a tangential direction, as we see the particles flying off from the rapidly rotating wheel; but gravitation restrains this tangential tendency, and holds the matter to its rotation, and the force becomes only a centrifugal force, counteracting and opposing the centripetal force of gravitation.

The centrifugal force increasing, an equatorial belt swells out; the poles are depressed, and the mass becomes an oblate sphere.

Condensation

from cooling now supervenes, and renders the exterior equatorial matter less mobile or more viscid; and this also tends to counteract gravitation, and, the specific gravity being increased, centrifugal force is still more increased, and, finally, in a portion of the equatorial protruding belt, the *centripetal* and *centrifugal* forces become equal, and being thus equal and perfectly balanced, it ceases to fall and stops in the form of a *ring;* but its revolving tendency is not interrupted.

The interior mass, being now relieved from its exterior encumbrance, is more volatile, and goes on falling as before, until, in obedience to the same laws, another ring detaches itself; then another, and another, till the sun has finally settled down to its present dimension of 883,000 miles in diameter.

Returning now to the first ring, we find that it has been gradually but constantly radiating its heat, and contracting; and that on one side, from some unknown cause, it has separated, and the annular mass, under the influence of its own interior gravitation, has, without the least shock or disturbance, gathered itself together in its grand orbit, in which it is still moving, with the same velocity and at the same distance from the prime centre as when it first separated.

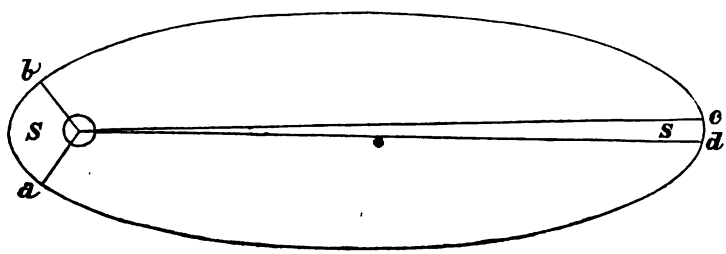
The same laws were operative in the separation and formation of satellites as of primaries. An interesting fact in support of our theory is, that two of the oft-shoots from Saturn still maintain their status as rings; no defect in their integrity having admitted of rupture.

After Jupiter had been segregated, it seems reasonable to suppose that the remaining primary mass might have been in some way unusually perturbed, so that the succeeding ring had many weak points, admitting of its breaking and forming many asteroids.

The mode of cometary segregation is different from that we have been considering; the tangential force, aided by heat, being the principal agent, which, modified by gravitation, gives the comets their extended and extremely elliptical orbits.

Cometary matter may have been thrown off, either from the prime solar mass, the primaries, the secondaries, or even from comets themselves.

The orbits of all the planets are elliptical, and those of the comets exceedingly so. The sun is always in one of the *foci* of the orbit, and the movement when in perihelion is more rapid than when in aphelion.



According to Kepler, the *radius vector* of an orbit describes equal areas in equal times. If we suppose the areas of *S* and *S*, in the figure, to be equal, the body will move from *a* to *b* in the same time as from *c* to *d*.

One comet has been observed to occupy but two hours in passing from node to node, a distance of 1,500,000 miles; with so rapid a movement and so quick a curve as that, would not a portion of matter be very likely to go off upon a tangent?

May we not suppose that possibly there may be some little comet performing its round every few years, which gives off a little spray at every perihelion passage, furnishing us with those brilliant

meteoric displays, from time to time, of which so much has been said and written?

It has been objected to the Nebular Theory that it fails to account for the eccentric movements of Herschel and Neptune, and the movements of Herschel's moons.

It seems to me that this may be explained on the supposition that the prime nebular mass was not a round and perfect sphere, but was irregular in its contour, eccentric and irregularly ovoid, and that this may account for the apparent irregularities as well as for the eccentricity of all the planetary orbs.

That finite minds cannot fully comprehend the *modus operandi* of some of the heavenly bodies is no good reason for rejecting a theory which accounts so beautifully for so many of the physical phenomena, and for still clinging to old hypotheses which account for nothing without doing violence to the principles of modern science.

Wiser heads may yet, and very soon, account rationally for what now seems mysterious.

The admirable and rational doctrine of correlation, conservation, and conversion of forces, before alluded to, must not be overlooked, and ours is the only theory that can harmonize with it and carry us back to a consistent beginning of the present order.

Some better and more rational theory than has ever yet been sought out must be offered before we can yield up this.

We find strong support in the remarkable relation which exists in the times, distances, and movements of the planets, showing a complete family relation among them.

I will give a simple rule, derived from a discovery of Bode, by which any one, for himself, can determine, nearly, the distance from the sun, and the time of revolution, of any primary planet.

For distance of planets from the sun add four to each of the following geometrical series of numbers: 0 — 3 — 6 — 12 — 24 — 48 — 96 — 192 — 384, — and we have the following numbers to represent the proportional distances of the several planets: —

Merc.	Ven.	Earth.	Mars.	Ast's	Jupt.	Sat.	Hers.	Nept.
4	7	10	16	28	52	100	196	388

Then we proceed by the following proportion, — 10 : the earth's distance [95,000,000 miles] :: the number for any other planet : its distance in miles.

The first line following gives the distances as computed by this rule; and the second, as given by astronomers, in round numbers, in millions of miles:—

Merc.	Ven.	Earth.	Mars.	Ast's.	Jupt.	Sat.	Hers.	Nept.
38	66.5	95	152	266	494	950	1.862	3.686
37	68	95	142		490	900	1.800	

For time of revolution, Kepler has demonstrated that "the squares of the times of revolution are to each other as the cubes of their mean distances." I need but state the law to give the rule.

It would seem by this that Mercury is the last planet that can be thrown off.

Let us now direct our attention to the sun and his sources of heat. Condensation always develops heat. The falling together of matter produces heat. The matter of our solar system which has not gone to form planets, satellites, comets, or meteorites, has fallen into the domain of the sun; and the matter which has fallen, as well as that upon which it has fallen, has become heated by the concussion and pressure (impact). But these are not the only sources of heat to the sun. As the molecules of matter have approached each other, they have slowly and gradually come within the sphere of chemical attraction, whose action, in combining chemically the elements of matter, is by far the greatest source of free heat of any and all others combined. This fact may be illustrated in many ways. Witness the burning of gas, and combustion of all kinds. Observe the combination of oxygen with a few grains of magnesium on heating. It is one of the lightest metals, yet its chemical relations are such as to develop intense light and heat in burning. In this we have true solar light and heat, which has been carefully conserved, stored up, and handed down to us for our present amusement and instruction. It was once a part of the sun; it is now an integral of the earth, and the earth was once an integral of the sun.

It was a favorite idea of Mr. George Stephenson that the light which we nightly obtain from burning coal, or other fuel, was a reproduction of that which had, at one time, been absorbed by vegetable substances from the sun.

Under the operation of the laws and forces before mentioned,

the sun has become, as we see it, a molten mass of incandescent matter, glowing with intense light and heat.

Let us examine it.

The telescope brings it near, and we discover that its disc is not uniformly bright. There are scattered upon it small dark spots, which are in a state of continual change; and again there are large black spots, surrounded by penumbræ, which are gradually shaded down from the black central part to the white light. They change from day to day, and even from hour to hour. They break up or contract, and finally disappear. They show all the signs of mobility, characteristic of masses floating in a molten liquid, and of melting and passing away. The spots are confined to a zone extending 30° each side of the equator, and they seldom continue longer than five or six weeks. They appear to occupy deep cavities in an incandescent gaseous or semi-gaseous envelope, or covering of a molten sea, and their penumbræ indicate what we might expect from currents converging and flowing in from the hot gaseous atmosphere over the dark cavity.

There are sometimes seen peculiarly marked lines, brighter than other parts of the surface, which are curved or deviate in branches. These are apparently immense waves on the solar sea, and seem to give evidence of disturbing causes there as well as here, producing winds, waves, currents, &c., only on a much larger scale.

As to what these spots really are many fanciful notions have been broached.

One is that they are the dark solid body of the sun itself laid bare to our view through openings in its luminous atmosphere. Lalande suggests that eminences, in the nature of mountains, are laid bare and project above the luminous ocean, appearing black above it. How he supposed these cold mountains got covered again, in the course of five or six weeks, we are left to conjecture.

This hypothesis of a cold sun, with a luminous atmosphere, is quite in keeping with that other hypothesis which is based on the assumption of a cold opaque sun, invested with a luminous or phosphorescent atmosphere, whose rays, in passing through our atmosphere, become heated by friction.

All such notions of a cold sun and cold sunbeams, bringing to us no other genial heat than what they get by friction in our atmosphere, are, in my estimation, quite too chilling. To credit them would be to prostrate the beautiful doctrine of *conservation of force* and *undulation of ether*, so well taught by modern science,

and so generally received by modern philosophers. Where could reside the conserved force necessary to endow an imponderable ray with the genial and vivifying heat of the sunbeam? Not in the atmosphere; certainly not in the ray. It is inconsistent with all our present knowledge of force.

It may not be out of place here for me to suggest an hypothesis in regard to the sun's spots.

When earthy matter, in a molten state, cools by radiation and crystallizes, it is lighter than the molten mass, and consequently floats upon it; but when the crystalline mass cools it contracts, becomes heavier, and tends to sink.

After contemplating the peculiar appearances, motions, and evolutions of the sun's spots, may we not conclude that it is possible, nay probable, that they are the manifestation of an effort on the part of nature, under the operation of well-known laws, at solar incrustation?

May not a mass, commencing to crystallize, extend its borders and increase upon its under surface, the upper portion at the same time cooling more and more, until the increasing specific gravity, aided by the buffetings of waves and currents, causes it to be submerged, and to melt and disappear?

If the sun is approaching a great astral winter, as we have suggested, it seems reasonable to suppose that the spots will increase, and that, in less perhaps than a million of years, they may so accumulate as finally to coalesce and form a solid crust like that of the earth. Then the "god of day" will cease to shine, and will be counted among the lost stars.

Now, according to the views which I have ventured herein to submit, the idea of a once universal chaos, from which all bodies appertaining to cosmic nature were created or evolved, is discarded, and that of the eternity of matter and motion is maintained. It is contended that all has ever been revolving, alternating, and changing in forms, and has never presented less of universal heterogeneity than at present.

This, it seems to me, is in accord with the great doctrine of the present century, viz., that of the Correlation and Persistence of Force, and is entirely consistent with the attributes of an Infinite, Eternal, Omnipotent, and Omnipresent God.

6. Description of a New Form of Mercurial Horizon in which Vibrations are speedily Extinguished. By J. Homer Lane, of Washington, D. C.

In the operations of the Office of Weights and Measures occasion has arisen for the use of the collimating mercurial horizon. This is not the place to report upon the special use to be made of it in this Office; but an improvement has been made in the mercurial horizon itself which is likely to prove valuable for the purposes of practical astronomy. At the united request, therefore, of the Superintendent and Assistant Superintendent of the Office of Weights and Measures, I here communicate a description of it for the American Association.

The improvement consists simply in reducing the depth of mercury in the trough to a very small quantity. This extinguishes the oscillations or waves which otherwise, upon the slightest causes, disturb the reflection when the horizon is used with a telescope.

The least depth with which pure mercury will overflow a hori zontal non-metallic plane surface is a little over one-eighth of an inch. If, however, the mercurial lake be left of this full depth at and near its boundary, with room for the capillary curve, then, inside this encircling space, the bottom of the trough may rise as near as we please to the level surface of the liquid. The first trough which we have tried on this plan is the only one that has been used prior to this current week of the present meeting of the Association. It was a wooden trough, formed in the lathe, with a horizontal circular plane or plateau, of six inches diameter, on a level something like one-sixth of an inch higher than the bottom of the deepest part of a margin of two inches wide all around it. The deepest part of this depressed margin was in the middle of its width, the object of the gentle slope so produced both on the inner and outer side being to soften the horizontal shocks which may be communicated to the mercury. But I think this is of little importance or value, since the capillary boundary will still be the origin of ripples produced by vertical shocks. The ripples of the surface of a mass of mercury produced by tremors are observed in fact to have their origin mainly at the borders; and this is the reason why the central flat plateau of the trough was made so large as six inches in diameter, while the clear aperture of the

telescope collimated over it was only from two to two and one-half inches in diameter.

In preparing the horizon the trough was first set very nearly horizontal by a spirit-level. A sufficient quantity of mercury was then poured in to overflow the whole bottom of the trough, at least with the aid of a little displacement. The large excess of mercury was then drawn off through a small hole which had been made at the deepest part of the deepened margin, and closed by a little plug. The mercury was allowed to flow until the level of its surface sank to the indication of a gauge laid across the top of the trough, leaving a very thin layer only on the plateau. The effect of this artifice in curing the disturbance produced by tremors was charming and complete.

But to secure this effect care must be taken that the depth of mercury on the plateau be reduced sufficiently. It is quite surprising to notice how small a depth is still sufficient to transmit across the plateau the little ripples that mar the sharpness of the reflection. I made no determination of the thickness used, but I think one-hundredth of an inch is small enough. It is easy, by gentle taps upon the trough as the mercury flows off, to notice when the ripples, with the diminishing depth, begin to grow sluggish, and when the point is reached at which they quickly die out on the plateau. Although the depth is so small when this effect is thoroughly secured, it yet very greatly transcends the thickness of a mere bubble or film of capillarity, and therefore there is no room to anticipate that the surface of the plateau will have any influence upon the horizontality of the upper surface of the mercury. In point of fact the horizon above described has been under the severest telescopic test, and yet the irregularities of the plateau were not sufficiently copied by the mercurial surface to mar the definition of the object-glass. To the same purpose I will state that on one occasion the trough was tilted slightly by pressure made on one side of it with a staff. Momentarily the mercurial surface tilted with the plateau, by a large quantity as seen in the telescope; but the changed inclination of the plateau being maintained by continuance of the pressure, the mercurial surface soon settled upon the inclined plateau into its original position of horizontality, any difference being at all events quite insensible in this imperfect experiment. We shall now, however, have opportunity to put this question to a more rigorous test with a cast-iron trough, which has just been completed, and which, by the kindness of Professor

Hilgard, I am permitted to submit, through him, to the inspection of the Association.

This iron trough has a circular plateau of about six inches in diameter. The deepened margin around the plateau increases the diameter to six and one-half inches. This deepened margin, at its outer boundary, is extended downward all around in a very narrow annular passage to the depth of three-fourths of an inch below the level of the plateau, where it opens horizontally outwards into an annular reservoir, one-half inch wide, which surrounds the plateau, and rises a fraction of an inch above it. This annular reservoir is closed air-tight above, but is provided with a screw-valve to control the passage of air. When this screw-valve is opened, and air forced in through a flexible tube with the mouth or otherwise, the mercury in the annular reservoir is forced through the annular passage and flows over the plateau, and is sufficient in quantity to flood it throughout. The continuity of surface over the plateau having been secured, the mercury is allowed to flow back into the annular reservoir; and the whole quantity of mercury may be adjusted so as to settle to the depth that is desired on the plateau. The rapidity of this return flow of the mercury may be controlled by checking the escape of air through the screw-valve. Should any accident cause the breaking of the film of mercury, the arrangement here described affords the means of its convenient and speedy renewal. The film will never break except by accident.

The screw-valve can also be used to suspend the return flow until the trough, which is furnished with levelling-screws, can be levelled by the surface of the mercury. Three steel points brought down upon the surface afford the means at once of levelling the trough, and of measuring the thickness of the film of mercury on the plateau.

II. OPTICS.

1. On Dispersion, and the Possibility of Attaining Perfect Achromatism. By Edward C. Pickering, of Boston, Mass.

When spectra are obtained with prisms of different materials, we find that the colors are unequally dispersed, one giving greater prominence to the red, another to the blue. Accordingly if we attempt to neutralize the effect of one by another, or to obtain achromatism, we always find that a certain amount of color remains, forming the residuary or secondary spectrum. Let us see what are the conditions, in order that this may disappear. Let α, α' be the angles of the two prisms, n, n' the indices of refraction for any ray, and D, D' the corresponding deviations. When the angles are small we have

$$D = (n-1)\,\alpha,\ D' = (n'-1)\,\alpha',$$

or the deviation of both prisms

$$D'' = D - D' = (n-1)\,\alpha - (n'-1)\,\alpha'.$$

Now Cauchy has shown that the index of refraction of a ray of wave-length λ is represented by the formula

$$n = A + \frac{B}{\lambda^2} + \frac{C}{\lambda^4} + \&c.$$

Substituting in the above formula, we have,

$$D'' = \left(A + \frac{B}{\lambda^2} + \frac{C}{\lambda^4} + \&c. - 1\right)\alpha - \left(A' + \frac{B'}{\lambda^2} + \frac{C'}{\lambda^4} + \&c. - 1\right)\alpha'$$

$$= (A-1)\,\alpha - (A'-1)\,\alpha' + \frac{B\alpha - B'\alpha'}{\lambda^2} + \frac{C\alpha - C'\alpha'}{\lambda^4} + \&c.,$$

and our condition is, that this shall be the same for all values of λ. By the rule for simultaneous equations all the co-efficients of λ must equal zero, or

$$B\alpha - B'\alpha' = 0,\ C\alpha - C'\alpha' = 0 \text{ or } \frac{\alpha}{\alpha'} = \frac{B'}{B} = \frac{C'}{C}.$$

The recent researches of Van der Willingen and others show that the succeeding terms may be neglected. Our last equation may be written in the form $\frac{B}{C} = \frac{B'}{C'}$; and we therefore see that, if we can find two substances in which this ratio shall be the same, by combining them we shall obtain perfect achromatism, provided the

angles of the prisms are in the ratio of B' to B. There is, however, one exception to this rule, for if

$$(A-1)\,B'-(A'-1)\,B=0 \text{ or } A=\frac{A'B+B'-B}{B'},$$

the value of D'' becomes 0, and there is achromatism, but no deviation.

If we attempt to apply these principles to the measurements of Dale and Gladstone, or even to those of Fraunhofer, we find that the errors of observations are so great that but little reliance can be placed on the results. We find, however, that $\frac{C}{B}$ for water, other liquids of small refrangibility, and crown-glass, is very small, and generally negative; of flint glass, it is considerable and positive; while with bisulphide of carbon, phosphorus, &c., it is positive and very large. The recent measurements of Van der Willingen afford data for more accurate calculation. In the following table the index of refraction is given by the formula

$$n=A+\frac{B(10)^2}{\lambda^2}+\frac{C(10)^6}{\lambda^4},$$

λ being given in millionths of a millimetre. The first five instances show the effect of adding sulphuric acid to water. The next three are measurements of distilled water, two by Van der Willingen, the third by Fraunhofer, and show how uncertain these constants still are. The last three relate to more refrangible substances.

Substance.	A	B	C	$\frac{C}{B}$
Distilled Water	1.323142	35.01	—48.8	—1.35
HO, SO_3 23.29	1.350940	40.70	—88.8	—2.18
" 47.22	1.380046	45.74	—123.0	—2.69
" 71.97	1.411199	49.71	—152.0	—3.06
" 94.72	1.419576	45.04	—116.1	—2.58
Distilled Water, V. d. W.	1.323228	35.30	—52.6	—1.49
" " "	1.323002	36.44	—67.6	—1.80
" " F.	1.323512	36.70	—66.1	—1.86
Flint Glass	1.714502	108.70	+665.2	+6.12
Hydrate Cinnamyl	1.575443	90.57	+2074.0	+22.90
Essence Anise	1.519745	73.68	+778.5	+10.57

If we had values of $\frac{C}{B}$ corresponding to all known transparent substances, we could at once determine which would be most suitable for a lens; it would, however, evidently be easy to select some substance as crown-glass, measure $\frac{C}{B}$ for it, and then prepare a

liquid as a mixture of sulphuric acid and water of exactly the right dispersion. The lens might be made of two disks of glass with the intervening space filled with the liquid. It is claimed that in this way the great defect in the achromatic lens may be remedied. Spherical aberration might be avoided mechanically, if lenses could easily be ground to ellipsoids or hyperboloids; but the removal of chromatic aberration, which is inherent in the nature of the substances used, has heretofore been generally considered impossible.

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2. On Methods of Illustrating Optical Meteorology, particularly the Formation of Halos and Coronæ, according to the Theory of Bravais. By Joseph Lovering, of Cambridge, Mass.

Optical Meteorology has been developed mathematically with greater success than any other department of this complex science. The principal features of a fully developed halo are: 1. The inner circle, concentric with the luminary, and having a radius of about 22°. 2. The outer circle, also concentric with the luminary, and having a radius of about 46°. Both of these circles, called the smaller and larger halos, are tinged with the colors of the spectrum, the blue being the outermost color. 3. The parhelion circle which passes through the luminary and is parallel to the horizon. This circle is white. 4. Upon this circle, and at a distance of 22° or more from the luminary, are two mock suns, the edge toward the sun being reddish and the opposite edge bluish. 5. A sort of tail stretching from these mock suns horizontally, and opposite to the line which connects them with the sun, to the distance of 43° 28′ or more from the sun. 6. The tangent curve to the inner halo. 7. The tangent curve to the outer halo.

All these features of the halo are satisfactorily explained by refraction and reflection, produced by hexagonal prisms of ice, floating or sinking in the higher regions of the atmosphere. These particles may be so situated as to present three independent cases. 1. They may be indiscriminately in all possible positions. 2. The axes of the prisms may be parallel and vertical, the sides of

the prisms facing all azimuths. 3. The axes of the prisms may be horizontal, but in all possible azimuths. The *first* case would exist when the particles of ice were newly formed, and had not accumulated so much velocity that the resistance of the air would bring the surface of least resistance to the front. If the three dimensions of the crystal were nearly the same, there would be no surface of least resistance, and the air would exercise no directing influence. The *second* case would arise, as the consequence of increasing velocity and resistance, if the *minimum* section of the prism were parallel to the base. The *third* case would arise under similar circumstances if the minimum section were perpendicular to the base. All three cases might coexist at the same moment, because some of the prisms were long and others short, and because some of the prisms had had less time than others to fall and accumulate velocity and resistance, since their first formation.

Of the various angles formed by the sides and ends of these prisms, some would exceed the limit of transmission, others would be zero, and produce no refraction. There would remain of the available angles, those of 60° made by alternate faces, and those of 90° made by the sides and ends of the prisms. The inner halo is caused by refraction through an angle of 60°, the refracting edges being parallel to the tangents to different parts of the halo. The outer halo is caused by refraction through an angle of 90°, the refracting edges of different prisms being parallel to different tangents. Both halos require that the prisms should be scattered at random, so that a sufficient number would be found in the required positions. The white parhelion circle is produced by reflection from the sides of the prisms when their axes are vertical. These same prisms, acting through the angle of 60°, would produce the *mock suns* whenever they stood in the position of minimum deviation, while others, not in the position of minimum deviation, would produce the colored appendages to the mock suns. These same prisms, acting through the angle of 90°, would cause the tangent curve to the larger halo of 46°. If the luminary were above the horizon, reflection from the upper end of these prisms would produce an uncolored image of the luminary underneath the real luminary; but this image would not be visible unless the observer were elevated to a great height above the surface of the earth. If the luminary were a little below the horizon, reflection from the lower end of these prisms would produce a similar image above the luminary and above the horizon, which would be visible; and hence the

luminary might appear to have risen again after setting. When the axes of the prisms are horizontal, refraction by the angle of 60° would cause the tangent curve to the inner halo of 22°. If large numbers of prisms were floating contemporaneously in all three positions, all these phenomena might coexist; otherwise only a portion of these various features would be displayed. It is evident, therefore, that both halos might be wanting, and yet one or both of the curves which are tangent to them might appear. If the tangent curve to the larger halo of 46° is seen, generally the *mock suns* and the *parhelion* circle are also seen, even in the absence of the halo itself. In other words, all which vertical prisms are capable of producing would generally, though not necessarily, be seen at the same time.

These general features are somewhat changed by the altitude of the sun or other luminary above the horizon. When the sun is in the horizon, the parhelia are at the same distance from it as the inner halo, and rest upon it. As the sun rises, they go outside of the halo and become impossible when the altitude of the sun exceeds 60° 45′. The lengths of the tails affixed to the mock suns increase as the sun rises, until the limiting angle of transmission is reached. There is an inferior as well as a superior tangent arc to the halo of 22°. Their figures are complex, and they join in a single curve circumscribing the halo itself, when the altitude of the sun exceeds 29° 15′. The inferior arc is rarely visible, unless the sun is more than 22° high. The halo of 46 is less bright than that of 22°, because it is larger and broader; and more light is reflected by the prisms under the larger incidences. The tangent curve to this halo is a circular arc having the zenith for its centre. It cannot be formed if the sun's altitude exceed 32° 12′. The semi-amplitude increases from 57° 48′ to 90°. But when it is 90°, its height is also 90°, and its radius is reduced to zero. The maximum brightness is in the middle of the whole arc. This arc actually touches the halo of 46° only when the altitude of the sun is 22° 8′. It sensibly touches between the altitudes of 15° and 28°. If the sun were in the horizon, the tangent arc would be 12° 4′ above the summit of the halo. If the sun were 30° high, the tangent arc would be 3° 39′ above the halo. The altitude of 22° 8′ is most favorable, because, in this case, the middle of the arc is formed by rays which have suffered a minimum deviation. A tangent arc to the lowermost point of this halo is not impossible, but rare. In this event, the light must enter a vertical face and emerge at the

base. The limits of altitude are complementary to those which the superior tangent requires; that is, the sun's altitude must be between 57° 48′ and 90°, the arc actually touching the halo at the special altitude of 67° 52′. If the axes of the prisms are shifted from a vertical to a horizontal position, the inferior and superior tangent arcs are changed to what are called *infra-lateral* and *supra-lateral*.

I have taken renewed interest in this theory of halos, which has been admirably developed by Bravais,* on account of the halo seen at Cambridge, January 6, 1870. This halo was seen about two o'clock, when the altitude of the sun was not far from 25°. The principal feature of the phenomenon, on that occasion, was the tangent curve to the halo of 46°, though the halo itself was not visible. At Waltham the mock suns were seen, but not the tangent curve. The tangent curve seemed to be a *complete* circle, and the colors were very vivid, the red being the outermost color, or nearest to the sun. I have stated that, theoretically, the *maximum* amplitude of this curve is 180°, and, if the sun had an altitude of 25°, the amplitude would be only about 138°. The history of halos furnishes but few examples of this extraordinary occurrence, — a complete circumzenithal circle. On the 24th January, 1838, Lambert † saw at Wetzler a circle, nearly complete, centred about the zenith, with vivid prismatic colors. On the 11th July, 1749, Anderon ‡ witnessed at Norwich, about five o'clock, P. M., when the sun was nearly 25° high, a *white* circle around the zenith. Bravais resorts to two expedients for explaining the enlargement of the circumzenithal arc into a complete circle, in a few rare cases. In the first place, the light may strike the vertical side of the prism too obliquely to be transmitted, so that, after being once or twice reflected upon other vertical sides, it may emerge from sides opposite to the usual ones. In the second place, each point of the arc originally produced causes a *parhelion circle*, all of which are superimposed upon the arc itself, as far as it extends. This last operation, however, would produce light without any discoloration. In the halo seen at Cambridge, the centre of the circle was decidedly south of the zenith. This fact requires us to suppose that the parallel axes of the prisms were not exactly vertical. A current in the atmosphere might change the direction of the descend-

* Journ. de L'École Polytechnique. Cahier 81. Tome xviii.

† Pogg. Ann. Physik und Chemie, xlvi. p. 660.

‡ Phil. Trans. xlvi. p. 203.

ing particles of ice; but could the lateral motion, *with* the air, and not *in* it, develop any new resistance which would direct their axes away from the zenith?

I will now exhibit an experiment with an equilateral triangular prism of glass, and also a hollow one filled with water. The axis is vertical, about which it is made to revolve rapidly by clock-work. With a single prism, and sunlight or any bright and circular artificial light, all those features of the halo may be artificially produced which have been referred to the action of many prisms of ice, with vertical axes; the single prism, in its motion, assuming, in rapid succession, all the possible positions of these many prisms in the atmosphere. The halos themselves can be produced artificially, either by a conical prism, or by artificial crystals formed upon a plate of glass, as shown by Brewster* and others.†

The sun and moon are sometimes encircled by what are called coronæ. A corona may be distinguished from a halo in many ways: 1. It is much smaller even than the smallest of the two halos. 2. It is not rigidly bound to almost invariable dimensions as the halo is. 3. When it is bright enough for the colors to be distinguished, the red is outside and the blue inside. 4. This arrangement of the colors, as well as the dimension of the circle, indicate that coronæ are not produced by refraction or reflection in crystals of ice, but by interference. The following experiments which I shall now exhibit to the members of the Association will illustrate this subject. When light is sent through the intervals between lines which have been nicely ruled upon glass, a series of colored fringes, parallel to the lines, result from the interference between rays which pass through different openings. If the glass were ruled with concentric circular lines, close together, these colored bands would become circular, and surround the source of light. By a rapid rotation of straight lines in their own plane, subjective rings result from the parallel fringes. In order to produce the required rotation without a material axis, which would intercept the rays of light from the eye of the observer, a platform is turned rapidly by clock-work. The border of this platform is covered with cloth. The circular frame in which the graduated glass is set rests upon this cloth, with its plane at right angles to the platform, and is rotated by friction. Friction-rollers at the sides and top hold it in its place in the absence of any material axis of rotation. If concentric

* A Treatise on Optics. Amer. edit. 1835, pp. 282, 283.
† Amer. Jour. xvi. 398.

black circles are accurately drawn upon paper, and then photographed upon glass, on a greatly reduced scale, the photographed plate might be substituted for that on which the lines had been scratched. Again, if a plate of glass is covered with india-ink, and then concentric circles are scratched upon the black surface, leaving the intermediate black rings, the same optical experiment can be performed. All four of these methods have been tried, but the finest and neatest circles were obtained by the last method; and the experimental result is very beautiful, especially if the ruled glass is placed immediately in front of the object-end of an opera-glass.

Although artificial coronæ of great beauty can be produced in this way, it is obvious that the coronæ of nature must have a much simpler origin. And theory shows, that if lycopodium powder, the particles of which are small and spherical, and of uniform size, is sprinkled upon glass, a luminous spot, seen through the glass, will be surrounded with several coronæ, which, if less bright than those produced by the concentric rulings, on that very account have a greater resemblance to those in Meteorology. It appears that, in this indiscriminate sprinkling, myriads of minute openings are left everywhere on the plate, enough being found in the required places for producing the colored rings. Of these the light takes advantage for developing a symmetrical effect, just as in the formation of the rainbow it selects those individual drops of moisture which serve its purpose, while the remainder of the drops are inoperative. A piece of very delicately ground glass accomplishes the same result. In the atmosphere the place of the lycopodium powder is filled by the particles of moisture existing in the vesicular state; and the smaller these particles the larger will be the diameters of the coronæ which they produce. In this way these particles are proved to vary between the .001 and the .002 of one inch in diameter.*

Coronæ indicate the presence of the *cumulus* cloud; but halos imply the *cirrus* cloud, floating at great heights, and within the region of perpetual congelation. For halos are seen even in the summer and in the tropics. By revealing the incipient gathering of the cirrus cloud, they may foretell the approach of a coming storm.

* Kaemtz's Complete Course of Meteorology, p. 111.

III. ACOUSTICS.

On a New Musical Notation. By Samuel D. Tillman, of Jersey City, N. J.

Symbols are the necessary outgrowth of systematic conceptions, therefore a notation may be a true index of progress. In Acoustics, and other branches of Natural Philosophy, the Ancients made but small advance for the want of correct measuring instruments. How much they accomplished in music is not now known, since they have left no record of musical conceptions. The Greeks advanced so far as to denote differences in the pitch of musical sounds by alphabetical and other characters, and to arrange these sounds in different orders which were designated as modes, but they had no symbols to denote duration, rest, rhythm, or dynamics. Their music was chiefly vocal, and, being learned by rote, was liable to undergo many changes. Strings and pipes were tuned to their different modes, and were used as accompaniments to the voice. The Muses of Epic and Erotic poetry were represented by the ancients as holding musical instruments. Sappho, Anacreon, and Pindar sung their own compositions. Their performances may have resembled chanting, but, more probably, they were of that semi-musical character now called Recitative.

Music, as a fine art, had its origin in the Christian Church. In the sixth century Pope Gregory first recognized the fact that the Diatonic scale consisted of seven sounds; and, as the extension of this scale, either upward or downward, gave sounds similar to the first series, he determined to designate the series by the first seven letters of the alphabet, commencing at the tonic in the minor mode, and to apply the same letters, slightly modified in form, to each similar series of higher or lower sounds. No further improvement in musical notation was made until Guido Aretinus, of Tuscany, early in the thirteenth century, introduced the solfeggio, and the staff of five lines, on the spaces and lines of which he made dots, upward and downward, to denote sounds of higher and lower pitch. These dots were afterwards so modified as to express the length or duration of the sounds. Various other improvements were subsequently added, and after the lapse of several centuries a complete system of harmony and counterpoint was introduced, and the notation then embraced all the characters now used. In the mean time the rates of vibration producing sounds of different

pitch were found to have fixed mathematical relations, and the laws of harmony became an important branch of Acoustics.

The complications in this present notation arise from two causes: 1st. In order to dispense with the use of leger-lines it was found essential to introduce three clefs, represented by distorted Gothic letters, which respectively defined the position on the staff of the sounds known as *F*, *C*, and *G*, and consequently the position of the other sounds of the Diatonic Scale. As the clefs may be used on any line or space of the staff, it follows that the signs belonging to the Diatonic Scale could have seven different interpretations, although in common practice they have only three. 2d. A change of the tonic from *A*, in the minor mode, or *C*, in the major mode, of the so-called natural key, to any other position, involves the use of other sounds, which are represented by placing the sign of a sharp or flat before either note of the natural key, thus indicating that such note is to be raised or lowered in pitch about a semitone. As the seven different positions given to the sounds of the Diatonic Scale may be virtually changed to two other positions by means of flats and sharps, the whole number of different interpretations would amount to twenty-one. In most of the printed music now used, only two clefs are found, and these respectively give *F* and *G* but one position, so that the different interpretations commonly applied to the same note on the staff amount to four.

Although this complicated system enables the musician to sing or play correctly, it does not always indicate with absolute accuracy the true pitch of the note represented. This point may be illustrated by a single example. In the key of *C*, the first interval — that is, from *C* to *D* — is approximately measured by nine commas; and the next interval, from *D* to *E*, by eight commas. If the tonic is changed from *C* to *D*, the next sound above it must be nine commas more acute than *D;* yet we see that in the first key used, the true *E* was only eight commas more acute than *D;* therefore, this sound, *E*, does not belong to the series of true sounds used in the key of *D*. The two sounds known as *E* in these two keys, differing in pitch about one comma, are represented in the notation as identical. In true modulation, much greater differences arise, which cannot be indicated by the common music-signs, but which the vocalist or violinist, by the ear alone, is able to render correctly. True intonation can only be given by instruments of the violin and trombone classes, to a limited extent by

the euharmonic organ, and by the human voice. The harp, piano, organ, melodeon, and all hand instruments operated by keys, are necessarily constructed according to a tempered system of intonation, by which a sound is so modified in pitch that it may be substituted for the true sounds belonging to the different tonics, and thus twelve sounds compose the tempered chromatic scale of each septave.

This admirable tempered system has greatly simplified the execution of difficult musical compositions, and enables a single performer to render several parts simultaneously on instruments like the piano and organ.

The query naturally arises, Cannot the notation be adapted to this tempered system used on all keyed instruments, and simplified by abolishing clefs, flats, and sharps? Several attempts have been made to accomplish this object. Among the first was that by the celebrated Jean Jacques Rousseau, who, in 1742, read a paper before the Academy of Science at Paris, "On proposed new signs for music." His system, with some modifications, has been revived within a few years past; and, it is said, was successfully taught to vocalists in the Paris Conservatory of Music, under the direction of the distinguished composer, Auber. The peculiar feature of that system is the use of the figures, long employed to denote chords, in place of notes on a staff. Three serious objections may be raised against it: 1st. It introduces the old defective counting by using the numeral 8 to denote the eighth sound in an upward progression on the Diatonic Scale, which sound is the first note of another series. 2d. It does not provide for modulations. 3d. It gives no fixed idea of pitch, since each sound is only known and distinguished by its relation to the tonic.

Assuming that it would be highly advantageous to employ symbols of sound exactly adapted to the tempered system of intonation used on all keyed instruments, I now present the following plan. It is based on the new method of distinguishing and measuring musical intervals laid by me before this Association at a previous meeting, in which the upward progress of the pitch of musical sounds is represented by a spiral projection, each ring measuring a septave, so that a *radius vector* cutting them would show the position of the same note in each septave; thus obviating the difficulty met with in measuring the seven intervals of the Diatonic Scale on a right line, which requires the addition of a superfluous note.

In representing the intervals of the septave, as used in the tempered system, one ring of the spiral is made a circle for convenience, and divided into twelve equal parts. These measure a tempered semitone interval, and may properly be termed the twelve grades of pitch belonging to one septave. They are numbered like a watch-dial, so that every person who carries a watch has at command a Chromatic Scale. The numerals 12, 2, 4, 5, 7, 9, 11, correspond with *C*, *D*, *E*, *F*, *G*, *A*, *B*, of the Diatonic Scale, and designate the seven white keys of the piano, while 1, 3, 6, 8, 10, denote the five black keys. As the natural key, or the tonic of *C*, is not employed more than other tonics, it seems essential not to give the sounds belonging to that key more prominence than other sounds; accordingly, in this system, all the notes are numbered by figures of the same size. By this method no allusion to flats and sharps is necessary. The notes belonging to any tonic are found by a very simple rule; namely, when the tonic is an even number the next two notes are even numbers, and the remaining four notes are odd numbers; and *vice versa:* when the tonic is an odd number the next two notes are odd, and the remaining four even. A single example will show the comparative simplicity of the new method. To the question, What are the notes belonging to the key of *B*, or the signature of five sharps? the answer, by the old system, is *B*, *C* sharp, *D* sharp, *E*, *F* sharp, *G* sharp, *A* sharp. By the new system, 11, 1, 3, 4, 6, 8, 10.

In devising symbols for this system, I have given each the same prominence; and they are derived from the graduated circle in this way: A square is drawn so as to include the circle; and by making three projections on each of the four sides of the square, twelve projections are formed, which are signs of the twelve notes of the tempered Chromatic Scale. The note *C*, or 12, being represented by the centre projection, on the upper side of the square, the other projections pointed out by the moving minute-hand of a watch, represent in regular order the remaining notes of a scale. When one sound is denoted, only one projection is used on the square; but more may be added to show the chords belonging to that sound. In printed music these squares will be from an eighth to a sixteenth of an inch in size.

The duration of sound, or the length of a given note, is measured by means of the same square, as follows: A square having four thick or full-faced sides is a sign for a semibreve, measuring four beats. A square with two thick sides is a minim, measuring two

beats. A square with one thick side is a crotchet, measuring one beat. A square with four thin sides is a quaver. The same square, with a vertical line through the centre, is a semiquaver; and the latter square, with a horizontal line added, is a quarto-quaver. A square with thin sides, having a diagonal line through it, is an octo-quaver; and this sign, with another diagonal line crossing the first, is a semi-octo-quaver, known in common parlance as a hemi-hemi-demi-semiquaver.

When either of these symbols of duration is used without a projection, it denotes rest, and measures a like interval of silence.

If the sounds to be indicated are all in the same septave, the symbols are placed in the same right line; sounds in the next septave above are indicated by raising the symbol just above, and sounds in the septave below, by placing the symbol just below the general line. The square denoting the middle septave is known as unmarked, and that denoting the next septave above has beneath it a single horizontal line; that for two septaves above has two lines beneath it: and thus each septave above is indicated by an additional line beneath the square. In like manner the septaves below the middle *C*, or 12, are respectively indicated by placing lines above the square. However, to denote the actual pitch of any sound, the 12 of the middle septave, commonly known as the middle *C*, is produced by 522 vibrations in a second, according to the new French Standard of pitch; and the same sound in each septave downward is made by halving the vibrations respectively, and those above by doubling the vibrations for each *C*, or 12. It is evident that by this arrangement — each grade being modified for more grave and acute sounds — and by the use of the sirene, the highest and lowest sounds perceptible to the human ear can be indicated and measured. To denote the pitch of every note of the different true scales which may be used, it would be better to dispense with such expressions as *B* double flat, *E* flat grave, *G* sharp acute, etc., and use a system which will at once show the absolute pitch, and its relations to the tempered system of intonation. It is true that a division of a septave into 363 parts would be required for absolute exactness; but we can adopt the division of the ordinary watch dial into twelve parts, or grades, also sixty smaller parts or commas, so as to express the relations of the isotonic tempered system, and the true system, and give the exact measure required; since we may assign to these finer divisions *an exact value*, so that 10, 9, 6, 10, 9, 10, 6, will indicate the true major and minor tones

and the so-called semitone,—the sum of these intervals being equal to sixty. Thus the true *E*, in the natural key, being one division less from the tonic than the tempered *E*, or 4, might be denoted in figures by $_{1}4$; one division greater than 4 being $4'$.

Any of the old symbols which can be printed in one right line may be used with the new, for denoting any modifications of sound. In some cases, other well-known signs may be substituted; as, for instance, in place of the old sign placed above two notes, called a slur, or tie, the ordinary hyphen may be employed to indicate the blending of two sounds.

The new symbols are to be used like ordinary type, so that music may be set up and printed with greater rapidity than by any of the present methods. Great economy of space is secured by the new system. An ordinary piece for the piano could be embraced in a single page, thus relieving the performer from the duty of turning over leaves when the hand should be otherwise occupied. The brevity of the plan proposed is such that printed music could be added to each hymn of the ordinary Hymn-Book, without materially increasing its size. However, economy of space and convenience of use are matters of inferior consideration, when compared with the great object to be accomplished; which is, to strip from written music every sign not essential to the use of instruments having only twelve keys for each septave, and to make the new signs as easily understood as is the actual method of using the instrument; so that we shall no longer hear of playing and singing by rote among those whose musical gifts would be greatly enhanced if unhampered by useless musical signs.

The author proposes no crusade against the old system. It is thoroughly established, and millions of dollars are now invested in music-books, and in metallic plates from which music is printed. Still, in this age of progress, we should not be true to ourselves if we did not make known what we regard to be "the better way" for accomplishing a desirable end, leaving its actual merits and importance to be determined by the unerring tests of time and experience.

IV. ELECTRICITY.

1. Abstract of a Research on a Simple Method of Measuring Electrical Conductivities by means of two equal and opposed magneto-electric currents or waves. By Alfred M. Mayer, of South Bethlehem, Penn.

General Description of the Method.

A magnet is firmly supported in a horizontal position, with a portion of its length projecting beyond a fixed stop. Over this free end of the magnet, and resting against the stop, are placed two similar flat spirals, formed of the same quality of copper wire, and having the turns of one spiral in a direction the reverse of those of the other. The spirals are clamped together, and their four terminal wires are carried vertically downwards into four separate cavities containing mercury, and these mercury-cups are so connected with a reflecting galvanometer that, when the spirals are together slid off the magnet, the two equal electric currents, thus generated, simultaneously tend to traverse the galvanometer in opposite directions, and therefore its needle remains stationary. If we now introduce into the circuit of one of the spirals a resistance equal to that introduced into the circuit of the other, the needle will still remain at rest when the spirals are slipped off the magnet; but, if the resistance placed in one circuit is greater or less than that placed in the other, there will be a deflection of the galvanometer needles when the spirals are removed. Thus, by introducing wires of different metals into the circuits, we can readily determine their relative conductivities by making them of such lengths that their resistances are equal; which condition is attained when, on sliding off the spirals, the needle remains absolutely at rest. If, in the latter case, the wires have equal diameters, then their conductivities are directly, and their resistances are inversely, as their lengths.

A modification of the above method has been devised, in which the magnet is replaced by the terrestrial magnetic force, and the spirals and the wires by two similar coils, from two to three feet in diameter, formed of the two wires whose conductivities are to be compared. These coils contain equal lengths of the same sized wires and the same number of turns; the direction of the turns being opposed in the two coils. The coils having been bound together are placed in a plane at right angles to the line of "the dip," and the four terminal wires are so connected with the reflecting

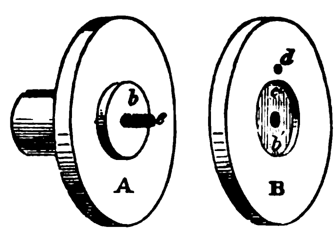
galvanometer that the two induced currents tend to traverse it in opposite directions. The coils are now quickly rotated through 180° around an axis at right angles to the line of the dip, and if the wires present equal resistances the needle remains at rest; if it is deflected, the direction and the amount of the deflection show which coil has the lesser resistance, and afford a means of estimating the same.

Description of the Apparatus.

The magnet was composed of three bars separated from each other by slips of wood .2 inch thick. Each bar was .27 inch thick and .9 inch wide. The middle bar was 10.4 inches long, and projected .25 inch beyond the two side-bars. The force of this magnet was equal to sustaining the weight of 1.5 lb. placed on the end of the middle magnet.

The spirals were formed of the best selected Lake Superior copper wire, $\frac{1}{20}$ inch in diameter, and "double covered." Each spiral contained one hundred and seventy-six inches of wire coiled in twenty turns, and the terminals were 15.5 inches long, thus making two hundred and seven inches of wire in each spiral. The exterior diameter of the spirals was 3.9 inches with a central opening of 1.7 inches.

The spirals were formed in this manner. An iron plate *A*, which screws on to the mandrel of a lathe, has cemented on to its face a disc of hardwood *b*, 1.7 inches in diameter and .1 inch thick. From the centre of the plate *A* projects a screw *e* which enters the wooden disc *B* at *e'*. When the plate *B* is screwed home, the disc *b* fits into the cavity *b'*, and the plates *A* and *B* are separated to a distance a little greater than the diameter of the covered wire,

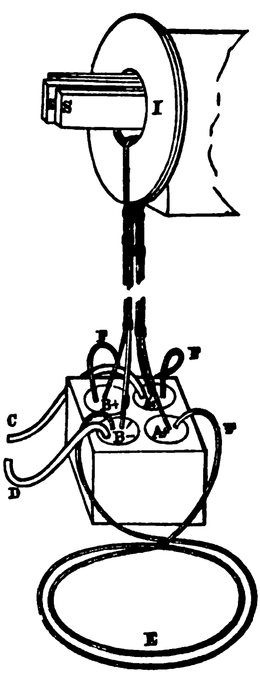


while the disc *b* forms a cylinder between them on which to wrap the spiral. The end of the wire to be coiled is passed through a hole *d* in the plate *B*, which is then screwed home on to *A*. The lathe is then turned so that the wire is coiled over the centre disc from *A* to *b*. After the space between the plates is filled with coils, the free end of the wire is secured and the plate *B* unscrewed, while the wire slides through *d*, and the coil is not unwrapped; which would have taken place if it had been coiled in the direction from *b* to *A*. The spiral is now saturated with very fluid paraffine, and has cemented on to it, with a hot chisel, a paper disc previ-

ously saturated with paraffine. The spiral is now removed, the covered side placed against the disc, and its other surface treated in the same manner. The spiral is then taken off the chuck, and on holding it up to the light the copper wire is distinctly seen through the translucent covering of the wire, and the paraffined paper cover of the spiral. The terminals are now led radially from the spirals, and are tightly bound together as described above. To still further strengthen the spirals, both they and their terminals are covered with a firm layer of shellac varnish.

The galvanometer was formed of a coil containing two layers of twenty-two turns each, of $\frac{1}{30}$ inch copper wire. The needles were 1.65 inches long, and distant from each other .6 inch. They were attached to a thin glass mirror, 1.2 inches square, which was suspended by a few fibres of unspun silk. These needles were so astatic that they made exactly $4\frac{1}{2}$ simple vibrations in one minute.

The telescope and scale with which the deflections of the needles were determined were placed at a distance of 2.285 metres from the mirror, so that a deflection of 1° of the mirror caused 8 centimetres of the scale to move over the thread of the telescope, and as I could read off to 1$^{m.m.}$ of the scale, it follows that a deflection of 45″ of the mirror could be measured.



Under the magnet, which was placed near the telescope, was a block of wood having four holes one inch in diameter, and one inch deep, containing mercury. Into these four cavities dip the four terminals of the spirals, and the standard wire used as a unit of resistance is placed in the circuit of one spiral, and the wire whose resistance is to be determined is placed in the circuit of the other. The length of this last wire can be altered readily, so that its resistance can be made equal to the unit of comparison. The two terminals of the galvanometer are so connected with these two circuits that the two induced currents, produced on sliding off the spirals from the magnet, tend to traverse the galvanometer coil in opposite directions.

EXAMPLES OF THE DETERMINATION OF ELECTRICAL CONDUCTIVITIES.

If the two spirals were exactly similar in form and equal in the resistances they presented, yet they would not be equal in action on the galvanometer-needle when they are slid off the magnet; for one of the spirals is further on the magnet than the other, and therefore cuts more "lines of magnetic force," and also the two spirals simultaneously pass over portions of the magnetic lines different in strength, therefore the rear spiral will have a stronger electric current induced in it than the front one. To balance the spirals a certain length of wire is introduced into the circuit of the rear spiral, so that when they are together slid off the magnet the needle remains at rest.

The above condition having been attained, I introduced into the circuit of one of the spirals one hundred and twenty inches of No. 18 "hard drawn" silver wire, which I supposed to be free from all alloy, and found that I had to introduce a length of one hundred and twenty-seven inches of similar pure copper wire into the other circuit, in order that the needle should remain at rest when the spirals were slipped off the magnet. Therefore, the resistance of one hundred and twenty-seven inches of the copper equals that of one hundred and twenty of the silver wire, and taking the copper as one hundred in conductivity we have

$$127 : 120 :: 100 : 94.48$$

Matthiessen * makes the ratio of the conductivity of silver to copper — both "hard drawn" — as 100 : 99.95, or nearly equal; but in my determination the silver is 5.5 per cent below the copper. I therefore suspected impurities in the silver, and an examination of the wire, kindly made by my colleague, Dr. Wetherill, showed that the silver contained about .01 per cent of gold and a trace of iron. This accounts for the low number found for the silver, and affords a beautiful illustration of Pouillet's remark, that the purity of a metal is most readily determined by a measure of its electrical conductivity. The electrical test of purity, however, far exceeds in delicacy the chemical examination; for a very minute percentage of alloy causes a great increase of resistance. If we could be sure that the wires we compared were in the same physical conditions as to annealing or hardness, we could probably use this method as a means of determining the percentage of a *known* metal which formed the alloy.

* Phil. Trans. 1858, 1862.

Pouillet * has shown that silver whose conductivity is one hundred when pure is only fifty-one when it contains .037 of alloy; and is forty-seven, forty-two, and thirty-nine when it contains respectively .100, .143, and .253 of alloy. Pure gold gave thirty-nine, but .049 of alloy reduced its conductivity to thirteen; and Jenkin has found that an alloy of one part of silver and two of gold presents almost as much resistance as german-silver.

The three following determinations were made of the conductivity of the best quality of iron wire relatively to that of the standard copper wire: —

(1). The resistance of 240 in. of copper wire = 36.7 in. of iron wire.
(2). " " 111.6 " " = 16.16 " "
(3). " " 60 " " = 8.67 " "

They give for the relative conductivity of iron:

(1).	240	:	36.7	::	100	:	15.29	
(2).	111.6	:	16.16	::	100	:	14.48	
(3).	60	:	8.67	::	100	:	14.45	
							14.74	= Mean.

The copper and iron wires in (3) were cut off from the lengths used in (2); but the wires used in (1) were taken from parts of the coil removed from (2) and (3): these facts account for the close agreement of (2) and (3), and the higher number obtained in (1).

E. Becquerel † gives 13.6 for the conductivity of iron, copper being one hundred, and both wires "hard drawn," while Matthiessen ‡ determines 100 : 16.81 as the ratio of hard-drawn copper and iron.

The mean of Becquerel and Matthiessen	=	15.20
Mayer	=	14.74
Difference	=	.46

Therefore it appears that my determination by means of the above method agrees closely with the mean of the measures of those distinguished experimentalists made by two different methods.

The Degree of Precision of the Method.

The degree of precision of this method, as applied with this special apparatus, was determined in the following manner. A copper wire, one hundred and twenty-three inches long, had opposed

* Traité de Physique, 1856, Vol. I., p. 606.
† Ann. de Ch. et de Phys. III., xvii. 266.
‡ Phil. Trans. 1858, 1862.

to it a resistance which was about equal to one hundred and twenty inches of its length. The mean deflection produced in the needle of the galvanometer, under these circumstances, was carefully determined. The copper wire was now shortened one inch, and the deflection again determined; this was repeated, determining the amount of deflection produced by each diminution of one inch in length until six inches had been cut off. These experiments showed that a diminution or increase of resistance of $\frac{1}{120}$th part in one of the wires will cause a deflection of 0.4 of a division of the scale, or of 3′ of arc in the galvanometer-needle. But we have seen that $\frac{1}{10}$th of a division can be read on the scale; therefore, we can with this special apparatus detect and measure an increased or diminished resistance of $\frac{1}{480}$th part. As the galvanometer can be removed to even twice the distance at which we read its deflections, I think I am safe in saying that with this method, as applied with the above apparatus, we can measure a difference of resistance in two conductors amounting to the $\frac{1}{960}$th part, which is far within the variation observed in wires of the same lengths and diameters taken from the same specimen of wire.

If a galvanometer formed of ten or twelve turns of $\frac{1}{10}$th inch copper wire had been used in connection with a larger magnetic battery and spirals of $\frac{1}{10}$th inch wire, while the galvanometer had been placed at a greater distance, I have no doubt that the degree of precision would have been equal to the measurement of $\frac{1}{1000}$th part of variation in resistance.

V. PHYSICS OF THE GLOBE.

1. Aurora Borealis. By L. Bradley, of Jersey City, N. J.

In treating the interesting and important subject of Aurora Borealis, I deem it necessary to premise by a general but brief examination of the phenomena, the causes and the effects of Atmospheric Electricity, in order that we may deduce, if possible, a rational theory of the essential nature of the aurora itself.

Atmospheric Electricity

plays an important part in all atmospheric phenomena, either as a cause, a concomitant, or an effect: the formation of fog; the fall of rain, and of snow; in storms generally; in lightning, and in many phenomena which do not possess the character of lightning.

Under the name of Castor and Pollux, the ancients designated the bright light which, in stormy weather, sometimes invests the projecting angles and the metallic parts of bodies.

Sailors tell us St. Elmos fires sometimes appear at the mastheads and yard-arms of ships, which, in extreme cases, make a peculiar noise, similar to that of electricity when it escapes into the air under the influence of powerful tension. Cases are related in which soldiers and cavalry have seen fires shining on the points of their bayonets and swords.

The spires of churches and other public buildings are sometimes enveloped in a similar manner. Most frequently these fires resemble, more or less, the brush, as of electricity in motion, but it sometimes happens that the light is concentrated into small globes without any trace of diverging jets. These are, doubtless, of electricity in the opposite direction or negative. But it is not only at the extremities of objects on the surface of the earth that luminous appearances are perceived in times of storms. Sometimes fog, rain, snow and hail are decidedly luminous; but it is snow which most frequently presents this phenomenon, which is now taken as unquestionably due to electricity. The electric property of snow is so decided that atmospheric electrometers are sometimes powerfully charged during a fall. According to Beccaria, a cloud charged with snow diffused in all directions a reddish light, sufficiently intense to enable one to read books printed on ordinary type.

Frequently, people in the midst of a storm become foci of electricity, which is not only manifested by a light, but by a particular whizzing noise.

Brewster cites the case of two English travellers, who, surprised in their descent of Etna by a heavy fall of snow, accompanied by violent claps of thunder, heard a hissing noise every time they extended their arms into the air, and, on extending a finger and moving it through this snowy atmosphere in various directions, and with rapidity, they were able, at pleasure, to generate a great variety of musical sounds, the intensity of which was such that they were perfectly heard at the distance of several yards. I shall endeavor to show presently that Aurora Borealis is a phenomenon similar in its essential character to those above cited, and that all are due to what has been called Atmospheric Electricity.

Causes of Atmospheric Electricity.

Many hypotheses have been propounded to explain the origin of Atmospheric Electricity.

Some have ascribed it to the friction of the air against the ground; some to the growth of plants, or to the evaporation of water; some have compared the earth to a vast voltaic pile; others to a thermo-electric apparatus. Some of these causes, and perhaps all, may concur, in some degree, in producing the phenomenon. According to the theory of Peltier, "the electrical phenomena of the atmosphere are entirely due to the induction of the earth, which is primarily and constantly negative."

It is difficult for me to conceive how the earth should be rendered thus constantly negative, unless there be some force constantly in operation, adequate to such disturbance of the electric equilibrium between the earth and its surrounding atmosphere. Do not the potent rays of the sun in their vaporizing effect constitute such a force?

Pouillet and others have shown that no electricity is produced by the evaporation of distilled water; but if an alkali or a salt is dissolved, even in small quantity, there is chemical disaggregation, and the vapor is positively, while the solution is negatively, electrified. The reverse is the case if the water contains acid. Volta was the first to show that the evaporation of water produced electricity. Now, as the waters of the whole ocean hold salts in solution, Pouillet is disposed to see in this evaporation the source

of atmospheric electricity. De Saussure concurs with Volta and Pouillet in this theory.

I take it therefore as established, that the vapor of the atmosphere, as a whole, is charged with positive, while the earth and ocean are charged with negative, electricity; although the solid earth and the sea are, in some degree, in opposite electrical states, the sea being positive and the earth negative. It is also a fact, now well established, that the higher we ascend, the more highly positive is the tension. Becquerel and Peltier have demonstrated this most clearly.

Quetelet, experimenting with a balloon and an electrometer, satisfied himself by a great number of observations that the electric intensity of the air increases proportionately to the height. I venture, therefore, to suggest the probability that, if an insulated conducting wire were to be erected, having a ground connection in a valley, and connected with a large surface of wire gauze above the top of a neighboring mountain, so as to form a good atmospheric connection, a current would be, at most times, propagated through the wire, sufficiently intense to operate a Morse telegraph, and that the higher the mountain the more intense would be the current. The intensity will be variable, however, according to the hygrometric condition of the atmosphere.

A positive cloud, too, coming near the upper portion of our telegraph line, may change its electric condition by induction so as to neutralize the current, or even to cause it to flow in the opposite direction.

Evaporation.

According to the learned Dr. Buist, quoted by Lieut. M. F. Maury in his "Physical Geography of the Sea," p. 11, the average evaporation from the ocean equals about nine feet of water per annum; *i. e.*, a stratum nine inches thick per month. This when evaporated would cause a stratum of steam, of 212° Fahr. and under ordinary atmospheric pressure, forty-three feet in thickness per day to be formed and condensed.

This, if I have figured correctly (supposing the sea to cover 150,000,000 square miles, and a cubic foot of water to weigh sixty-two and one-half pounds), amounts to 2,157,463,500 tons to be evaporated per minute. This amount is diffused daily through the atmosphere. Now, if the smallest evolution of vapor from salt water gives an effect, appreciable by the electrometer, is it not

surprising that, in the formation and condensation of the immense amount shown by these figures, we do not encounter infinitely more of visible phenomena than we do?

We have now seen that the atmosphere is constantly charged with positive electricity furnished by the vapors that arise from the sea, and that the earth is negatively electrized.

Tropical Currents.

In the tropical regions, where the water is most salt, and evaporation most abundant, there is an upward current which carries the vapor to a great height, and then, setting out both north and south, constitutes tropical currents, which descend in proportion as they reach the higher latitudes. On reaching a region sufficiently cold, precipitation of snow, or of ice in some other form, takes place, in which electrical phenomena are almost sure to appear. Under the tropical currents are boreal and austral currents on their way to take the place of the ascending heated air of the tropical region.

The enormous amount of electrified vapors, rising high in the torrid zone, and then descending as they approach the poles, comes in contact with many conflicting conditions in the atmospheric strata which underlie them; so that the neutralization of their positive electricity is allowed to occur very differently at different times and places, and under different circumstances. All these are comparatively local, and are variable according as they are over the ocean, the land, or fresh-water lakes, and according to variations of temperature, and the different electrical conditions met with. In many regions of the temperate zones, vapors arise which are negative compared with those of the superincumbent tropical current. Hence arise the many meteorological phenomena in which atmospheric electricity plays so important a part, and in which we sometimes witness the most terrific consequences.

Storms.

The violent phenomena with which we are most familiar are storms with rain, lightning, and hail. Every particle of cloud or fog is known to be positively electrified, and to exist in the form of a small spherical balloon in which a small pellicle of water serves as an envelope to the interior air. This may be verified by

any one who will let some of the particles fall upon a slip of glass and submit them to microscopic inspection. Now this covering of water possesses all the positive electricity which was distributed in the vapor which composed it. The size of these vesicular globes is maintained at the point of balance between the repulsive force of the electricity and the cohesion of the water.

When such globules, in infinite number, collect to form a cloud, we must not suppose that the cloud is, as it were, a conductor, all of whose electricity is at once transferred to the surface. On the contrary the globules preserve their insulation and their individual electricity, and do not part with it, except in a manner very slow, according as the interstlcial air may be more or less conductive. In this way some of the electricity of the interior globules does slowly approach the surface of the cloud, thus enabling the globules individually to contract and severally to coalesce, forming drops which fall, carrying their remaining electricity to the earth. Presently a high degree of tension is acquired at the surface of the cloud, near the negative earth, or near an adjacent cloud which has been rendered negative by induction; and a discharge takes place in the form of a flash of lightning. This makes way for still further discharges from the interior globules, and facilitates a more liberal formation of the rain drops.

I have often observed the sudden increase in the torrents of rain commencing in a few seconds, and continuing for a few, after a heavy clap of thunder. One clap follows another and another: but such discharges never deprive the cloud of the whole of its electricity; for, as soon as the excessive tension of the surface is so far reduced as to admit of the collapse of the little balloon, they commingle, form drops, and fall; and in this way a large portion of the positive electricity of a cloud is carried silently to the earth. At every disruptive discharge a disaggregation of matter must occur, or no light can be evolved. In the case of every flash of lightning, a portion of the vapor of water is resolved into its elements, oxygen and hydrogen. The oxygen unites with the free nitrogen of the air, and forms nitrous acid. The hydrogen unites also with the nitrogen to form ammonia. The nitrous acid and ammonia unite, forming nitrite of ammonia. This salt is dissolved in the rain drops; is absorbed in the ground; imbibed by the roots of plants; then passed into other combinations by the leaves and other organs; then it appears in the fruits; is eaten by animals and men, thus aiding to form their bodies. In this we have one of

the many beautiful and mysterious agencies, employed by the great Supreme Intelligence, in the wonderful works of creation and providence. Ozone, too, is formed in every discharge, the importance of which, in the economy of nature, is not so well understood.

The phenomena and effects of a common thunder-shower, as given above, are simple compared with those of many great storms. In order to understand the electric action and movements of clouds, we must be familiarized with the idea of the *individualities* of the globules, and of the other constituents of which the clouds are composed. The globules are grouped into flakes, having their limits and their sphere of action like the globules themselves; the flakes in grouping form mamillæ; these in their reunion form a cloudlet, and the cloudlets form definite clouds; the grouping of definite clouds forms a cumulus, and several cumuli form a nimbus or rain cloud. By regarding in this manner the electric state of the clouds, which is in accordance with observation, we are enabled to comprehend their enormous power of attraction in some cases, and the other phenomena which they present.

It is easy now to conceive how rain and snow are found to be charged with an electricity which they carry with them in their fall. Each drop or flake must possess the electricity which was possessed by the globules which formed it. We can see, also, how snow or other particles of ice in the atmosphere may, under certain circumstances, become luminous. The electrometer sometimes detects negative electricity in a cloud, and in rain, snow, and hail; but M. Palmier and others now think that this is only an effect of induction, and that no cloud can be intrinsically negative.

Every positively charged cloud must have a concentric region about it, which is made negative by induction, and it has happened that persons have been killed by lightning, or rather what is called a return shock, in a clear atmosphere, in consequence of such induction. This is a phenomenon easily explained. When a storm cloud is powerfully electrified positively, and a person is situated within its sphere of activity, he becomes powerfully charged by induction with negative electricity; the natural electricity of the person being decomposed, and the positive repelled into the earth. Now, if the cloud is suddenly discharged by any means, and deprived of a large portion of its positive electricity, the natural electricity of the person is just as suddenly restored, and the shock

may be such on the nervous system as to destroy life. Brydon has related a remarkable case of this kind, in which a man named Lauder, who was driving a coal cart, was killed, together with his horses, when the sun was shining, and no rain was falling in the neighborhood; but a heavy clap was heard at the time by others from a cloud not far distant.

Beside this phenomenon of return shock, there are lightnings of three distinct kinds: —

First, — Zigzag, or Forked Lightning.

These present themselves under the form of a thin trail of white light; very defined; sinuous in its course; able to divide into two, and more rarely into three branches; directing themselves generally towards the earth, but frequently darting from one group of clouds to another. The clouds and the earth, or two oppositely electrified clouds, correspond to the coatings of a Leyden jar, and the intervening air to the glass of the jar; the thunder-storm is a charging and a discharging of a huge system of this kind. The zigzag and forked conditions are undoubtedly due to the resistance which the discharges encounter in the strata of air through which they pass.

Second, — Sheet Lightning.

Lightnings of this class present a light which, instead of being concentrated into lines without apparent breadth, embrace, on the contrary, immense surfaces. They have neither the whiteness nor the vivacity of forked lightning; are more sluggish, occupying appreciable time in their discharges; their tint is generally of intense red, though other colors sometimes prevail. Their bright light sometimes embraces the whole superficial extent of cloud, and even of a whole group of clouds; at others, only part of a cloud, or the border; it is frequently undulatory and flickering. The discharges appear to be interstitial, darting among the globules or ultimate vesicles of the cloud, which seem to serve a purpose in some way resembling the metallic particles of the spangled pane of the lecture room. Sometimes the discharges appear to be made among the larger individualities of the cloud, and are exhibited in great numbers of interior flashes and zigzag

flames of red light, following each other in almost continual succession.

The lightnings of this second class are the most numerous of any, and are especially interesting on the present occasion on account of the analogy existing between their genesis and that of the Aurora Borealis.

Silent flashes of lightning are frequently seen along a cloudless horizon, formerly called *heat lightnings*. Since the establishment of the telegraph we learn that they are the lightnings of real storms; so far away as to be entirely below the plane of the horizon, and too far off to be heard.

Third,—Ball Lightning.

Lightnings of this class are much less numerous than those of any other, and are by far the most difficult of comprehension, having never been satisfactorily accounted for. They are veritable globes of fire, several inches in diameter, and are transported from the cloud to the earth with sufficient slowness to be distinctly followed by the eye, being visible for two or three and even for ten seconds. They sometimes divide and rebound upon the ground several times; sometimes they burst, causing the detonation of heavy ordnance. They sometimes enter dwellings, barns, and outhouses, enveloping the whole building in flames in an instant. They seem to pay no regard to conductors, either good or bad.

Great and Violent Storms.

As to the causes, and the modes of generation of the great and violent storms, I will suppose a case, which, with modifications, may be taken as analogous to a majority of those which do occur.

In the torrid zone, and during the hot seasons in the temperate zones, a sultry heat, with a tranquil and humid atmosphere, may be taken as a precursor of storm. This may continue for days; the power of evaporation being great, the air becomes more humid, and, as Tyndall, Melloni, and others, have demonstrated, humidity is a powerful absorbent of heat; it is, in a measure, opaque to the heating rays; it therefore absorbs largely the sun's rays, as well as the radiant and reflected heat from the earth. The more the air is heated the more its capacity for aqueous vapor is augmented, and the greater is the absorption of heat.

But although vapor absorbs heat it radiates it also. Whence then can it radiate?

The lower stratum is superposed by strata, which are saturated too; it may, therefore, radiate into vapor, but the vapor radiates into it, also. The tendency, then, is for the air near the earth to retain its high degree of heat; to become rarified, and to rise; and from some quarter cooler air must come in to take its place. What then must occur in our ascending column of heated, humid air? For a time the radiation is intercepted, and, in great part, returned by the surrounding vapor; condensation, under such circumstances, cannot take place. But the quantity of aqueous vapor naturally diminishes as we ascend; its tension diminishes more rapidly than that of the air, and, at length, the humid stratum finds itself above the protection which had overspread it, and in the presence of purer space, where it pours its heat into, and with but little return from, the interstellar ether. This free radiation into space, together with the chilling effect due to the expansion of the ascending air, affords ample physical cause for the condensation of vapor and the generation of clouds. Cumuli are now formed, a stratum of which may extend over a large surface. Each visible cumulus forms the capital of an invisible pillar of saturated air. To take an extreme case, let us suppose that, the sky being now overcast, and the process of cooling going on more rapidly, another stratum is formed lower down than the first, and then another still lower. Cases are on record in which not less than three such strata have been distinctly observed. Now let it be remembered that each stratum, in its relation to those above or below, maintains its own independent insulation and electric individuality, the same as do the several clouds, cloudlets, or globules, as mentioned before, and that several individualities, charged with like electricity, repel each other; but no one can be so repelled as to impinge, unduly, on those beyond it; all are maintained *in equilibrio* in the mass, which, by their agglomeration, they help to compose.

Now it must happen that all the individualities of *every grade* become, as it were, polarized, for the reason that, above them *all*, is an atmosphere, highly positive, and below them the earth, which is negative. The positive atmosphere induces negative electricity in the upper portion of the upper stratum, driving the positive into the lower portion, by which its normal tension is largely increased. This acts in the same manner upon the next stratum below. The

negative earth, too, is acting to produce the same effect upward. It induces positive tension in the lower portion of the lower stratum, and that in the lower portion of the next, and so on.

Under such a system of actions and reactions among the several individualities between the negative earth and the upper positive atmosphere, the surface of the earth must become endowed with a negative tension very far beyond that which is natural or common, and the lower portion of the lower stratum must also acquire a positive tension far beyond what it could possibly attain, if it were not so largely reënforced by the strata above.

They all act, like so many spans of horses, one before another, drawing in the same direction. The amount of lifting force, then, exerted by such a stupendous magnetic battery, which in some cases may act, nay, does act, upon a single square mile of earth, it is scarcely within the scope of the imagination to conceive: it can be estimated only by millions of tons.

All loose substances, as well as trees, buildings, etc., are rendered powerfully negative, and are, therefore, repelled by the negative earth, while they are powerfully attracted by the superincumbent cumuli. Now we can see the *rationale* of those remarkable phenomena, the *ras de marée*, in which the sea is raised to the height of three or four, and even to six or seven, feet. They consist in the changes of level that are suddenly manifested, without there being any thing that can cause them to be anticipated.

Bertrand was the first to conceive and to explain that it was by the attraction of electric clouds that the waters were thus raised. We can now see why it is that sometimes, when a heavy cloud is hanging over us, the leaves, dust, and other light substances, when agitated by the slightest breeze, seem to have lost their gravity, and to rise high up without any apparent cause adequate to the production of any such effect.

The disastrous and terrific work of tornadoes, cyclones, and water-spouts is now accounted for, in which a slight gyratory behavior of conflicting winds is augmented into a force to tear up trees and carry them to great height; to lay waste buildings, and unmast ships; to carry up vast columns of vesicular vapor, and sometimes even whole water; emptying ponds of their contents, giving rise to those showers of solid substances, sometimes even living ones, such as frogs and fishes, which are noticed from time to time.

The great snake story of Illinois, said to be the greatest on record, reported in the "Illinois State Register," of June 1st, 1869,

and copied in the "New York Sun," of the 6th, is remarkable. We are told that after a fearful tornado, which occurred on Friday night, May 28th, every ditch, brook, and pool, on the prairie north of Taylorville, was literally alive with nondescript reptiles, some of which were from one and a half to two feet long. Whether this be fact or fiction, it is, to say the least, plausible.

And now, while writing, the "Louisville Commercial," of January 19th, 1870, brings the account of a terrible tornado, which occurred on the morning of the 17th, before the break of day, at Cave City, Ky., a town of four hundred inhabitants, by which nearly the whole of it was laid in ruins; fifteen persons killed, and twenty-five seriously injured. In this, trees, ten to twenty inches in diameter, were wrenched up by the roots; some were twisted into fantastic shapes, splintered, and strown about; others were carried bodily hundreds of feet; buildings were torn to pieces, and scattered like chaff, leaving not a vestige to mark the places of once peaceful and happy homes. A house was struck, violently turned around, struck again, and almost instantly levelled to the ground. The furniture disappeared entirely, was smashed to pieces, and borne on the wild winds beyond the limits of the town. The bursting and detonations of ball lightning were of remarkable frequency during the passage of this cyclone, which extended some ten or twelve miles.

In the formation of two or more distinct strata of clouds as described above, is to be found the condition which, according to most philosophers, is indispensable in the production of hail. It is known that water under some conditions may remain in a liquid state at a temperature many degrees below the freezing point, and that it may instantly congeal under some mechanical agitation. Now the water at the upper surface of a cloud may be in such a state. We can, therefore, see how aggregation in the form of sleet falling from a superposed stratum may produce the necessary agitation, and thus become immediately coated with a laminated covering of ice, forming hailstones. But I will not dwell further on this complex subject.

Aurora Borealis

is a phenomenon which I take to be as fully due to atmospheric electricity as are any of those before considered.

According to the testimony of all observers, this phenomenon is always accompanied by a peculiar *haze* or *veil*, which, although

allowing the light of the stars to pass, gives the sky a sombre aspect.

This haze is known to be composed of fine transparent needles of ice. M.M. Bixio and Baral, being raised in a balloon to a great height, found themselves, on a sudden, although the sky was serene and the atmosphere cloudless, in the midst of a perfectly transparent veil, formed of a multitude of little icy needles, so fine that they were scarcely visible.

Dr. Richardson, in a temperature of 57° below freezing point, having seen an aurora, the arch of which was near the zenith, remarked that, although the sky appeared perfectly serene during the display, a fine snow was falling scarcely perceptible to the naked eye. At another time he witnessed a similar fact under a brilliant sun, the rays of which permitted him to distinctly see the transparent icy needles. Gisler says that, in Sweden, upon the high mountains, the traveller is sometimes suddenly enveloped in a transparent fog, of a whitish gray color, passing into green, which is transformed into an Aurora Borealis. When such haze or particles of ice are precipitated from vapor, highly electrized, the electricity becomes free and luminous, as was the case in the snow cloud described by Beccaria.

We are led to the conclusion, therefore, that the aurora arises from electric discharges which take place between the luminous icy particles suspended in the air, and which in infinite numbers communicate with the earth or moist air below.

The arch from which the auroral streamers are seen to radiate is the boundary between the cold region, occupied by the icy needles, and the milder region of moist air in which the discharges cease to be luminous.

We may suppose that the production of auroræ in the arctic and antartic regions should be the normal state, and of daily occurrence, in which the establishment of electric equilibrium between the great tropical current and the earth should be manifested.

And so it would, were it not that this great current has met with many interruptions, and been often arrested in its regular course, by such disturbances in the underlying strata as I have before mentioned; so much so, indeed, that, whenever any portion of it is transported to the polar regions, it forms rather the exception than the rule.

But occasionally it does, in part, reach the high latitudes, and then aurora polaris can scarcely fail to appear.

These icy needles, generated in a region of intense cold, are peculiar. Unlike the congelation of sleet and hail, or the crystallization of snow-flakes, from particles of water, they are precipitated directly from the transparent vapor, without its passing through the intermediate liquid state. Like the ultimate vesicles and other individualities of a cloud, they maintain their own independent electrical spheres, and not only repel each other, but are, from their very inception, polarized.

The molecules of the vapor, too, of which they are formed, I infer, were polarized, and were, therefore, forced to unite in the exact manner to give them their pecular filamentous or needle-like form. Being precipitated from vapor, intensely positive, they themselves are endowed with positive electricity equally intense.

How, then, must they dispose themselves in their relation to each othêr, when floating freely in the air? Certainly in parallelism, and with their positive poles directed towards the negative earth; therefore, when discharges between such haze and the earth, or the lower stratum of moist air, become visible, they must appear in lines parallel with the direction of the icy needles. How beautifully apparent, then, is the *rationale* of these splendid displays; the flickerings, the streamers, the coronæ, and the *merry dancers*, all moving in exact obedience to the slightest electric or atmospheric changes! But

Terrestrial Magnetism

has an effect in a way not yet well understood, in modifying and giving direction to the auroral movements. The well-known effects of a magnet upon the electric arch between the poles of a powerful battery, and upon discharges through rarified air, are supposed to present some analogy to this terrestrial magnetic effect.

We are now obliged to discard the idea of extra-atmospheric aurora, as well as that of reflected solar light, and must admit that the phenomenon is confined to the regions where haze and cirrus clouds are wont to form; and, from the abundant evidence we have of their frequent presence in regions very low down, we are relieved from the necessity of supposing that the rarity of the air in the high regions is indispensable to the transmission of aurora, although we know that the more rare the air (within certain limits) the greater is the facility offered by it for the transmission.

Aurora not high up.

In proof that aurora may not always be high up, I quote the following: —

"Captain Franklin saw an Aurora Borealis, the light of which appeared to him to illuminate the lower surface of a stratum of clouds, whilst twenty-five miles further on, Mr. Kendall, who had watched the whole night without losing sight of the sky, did not perceive any trace of light."

"Captain Parry saw an Aurora Borealis display itself against the side of a mountain."

"Lieut. Hood and Dr. Richardson, being placed at a distance of about forty-three miles from each other, in order to make simultaneous observations, whence they might deduce the parallax of the phenomenon, and consequently its height, were led to recognize that it had not a greater elevation than five miles."

Finally, "M. Liais, having had the opportunity of applying a method of his to the measurement of an aurora, seen at Cherbourg, Oct. 31st, 1853, found that the arc of the aurora was about two and one-half miles above the ground at its lower edge."

The Noise of Aurora.

The whizzing, or noise of crepitation, often heard by observers in high latitudes, although denied by some learned philosophers, presents to my mind ample evidence of the low position of many auroræ.

I quote further:

"M. Verder, on the night of Oct. 13th, 1819, being in the latitude of Newfoundland, heard very distinctly a sort of crackling noise or crepitation, when the building that he ascended was in the midst of an aurora."

"It is generally admitted by the inhabitants of the northern regions that, when the aurora appears low, a crackling is heard similar to the electric spark."

"M. Ramm, inspector of forests in Norway, wrote M. Hansteen that he had heard the noise, and that it always coincided with the luminous jets."

"Dr. Gissler, who for a long time dwelt in the north of Sweden, remarked that the matter of Aurora Borealis sometimes descends so low that it touches the ground; at the summit of high mountains it produces upon the face of the traveller an effect analogous to that of wind."

Any one who has placed his face or hand near an intensely

charged prime conductor cannot fail to understand the nature of the effect here spoken of.

"Dr. Gissler adds, that he has frequently heard the noise of aurora, and that it resembles a strong wind, or the whizzing that certain chemical matters produce in the act of decomposition."

If the electric discharges through the haze are interstitial, darting from needle to needle, as they undoubtedly are, we cannot doubt that such crepitation would be observed by persons near enough to hear it.

The Odor of Ozone.

The pungent odor spoken of, as observed by some who have heard the noise, goes far to strengthen the evidences here cited. This odor is undoubtedly that of ozone, which is evolved as well in the infinitesimal discharges of aurora as in flashes of lightning; it is represented as identical with that observed at the discharge of a powerful Leyden jar, and is, without doubt, from the same cause.

In view of the foregoing evidence, it seems to me that there must have been some fallacy in the parallaxes which have placed auroræ at the great heights of four, five, and six hundred miles; for at such elevations there is no appreciable atmosphere, or, at most, it is too rare to sustain clouds or haze of any kind.

Is it not probable that the appearances presented by a haze in a given region may change, according to the point from which it is observed; or may it not present an aurora at one point, and be dark at another? Might it not have been so in the case of Franklin and Kendall, above quoted?

Arago held that to attempt to measure the height of an aurora was as futile as to attempt to measure the height of a rainbow. It is, indeed, certain that, in some points of view, each observer does see his own Aurora Borealis as he sees his own rainbow.

Electric Storms.

Aurora Borealis has so generally been accompanied and preceded by great disturbances of the magnetic needle, that it has been called a magnetic phenomenon; and the general operation which causes such disturbances, as well as the remarkable effects upon the telegraph wires, in sometimes neutralizing, and, at others, greatly augmenting the force of the battery current, has been called a magnetic storm.

I prefer to call it an *electric storm;* for it is no more nor less than an operation of atmospheric electricity moving in alternate and varying directions.

Electricity passing a magnetized needle, in any direction except in a line directly transverse to the magnetic meridian, always causes it to diverge more or less, as when a current passes through a galvanometer coil; it is, therefore, as much an electric phenomenon as the deviation of the galvanometer, or as the battery current itself. We might as well call a common thunder-storm *magnetic,* for it produces effects in all respects similar, but still more energetic and rapid.

Coincidence with spots on the Sun.

A peculiar and interesting circumstance appertaining to auroræ is their periodic coincidence with the appearance of spots on the sun.

The records go to show that the two phenomena have their maxima and minima nearly simultaneously.

Commencing with the year 1763, the maxima of spots, and of the aurora, appear in the following: —

MAXIMA.		MAXIMA.	
From 1763		From 1816	
to 1769	6 years	to 1830	14 years
" 1779	10 "	" 1837	7 "
" 1788	9 "	" 1848	11 "
" 1804	16 "	" 1860	12 "
" 1816	12 "		

The length of the periods varies from six to sixteen years.

The sun evidently possesses powerful electro-dynamic properties as well as magnetic polarity.

Although the forces which act upon the magnetic needle emanate directly from the earth, and are probably induced, in part at least, by electric currents circulating around it, still the prime source of all such induction is undoubtedly to be found in the sun itself, in its electro-dynamic and magnetic forces.

Now, the auroral phenomena being influenced as we see them by terrestrial magnetism it is not difficult to comprehend how any such great disturbances as must be produced in the sun's emana-

tion, by the formation of large spots on its surface, may be the occasion of the coincidence mentioned.

I apprehend that if physicists will hereafter bring their imaginations nearer to the earth in their investigations of auroral displays, and will candidly consider the facts and hypotheses above detailed, they will be able to see that they are inter-atmospheric phenomena, as simple, and as easily accounted for, as are halos, lightnings, clouds, or rainbows.

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2. The Northers of Texas. By Solomon Sias, of Charlotteville, N. Y.

Among the meteorological phenomena peculiar to Texas are what are termed "the Northers" from the main direction of the wind. In 1858, Prof. Joseph Henry gave a general explanation of their occurrence; yet, as a whole, no phenomenon is less understood, nor is there any respecting which so extravagant stories are told, and it is the object of this essay to present some of the phenomena connected with them, and, if possible, lay the ghost of exaggeration. The observations were taken from 1859 to 1866, in lat. 33° 40′ N., long. 96° 13′ W.

Commencement.

The wind from whatever quarter blowing, usually S., S.E., or S. W., either dies entirely away or very materially slackens, and is changed to a cold, piercing, north wind. This is a Norther. Sometimes the wind slowly veers through the west to the north, coming so gently at first that it does not turn the wind-vane, and can only be detected by the smoke which lazily floats southward. In a few hours this increases, until, on the Smithsonian scale, it reaches a maximum force of three or four (or velocity varying from twelve to twenty-five miles per hour), sometimes six; holds this rate several hours, perhaps a day or two; then gradually slackens, or comes in gusts mixed with an easterly or south-easterly current; and finally disappears, a south wind prevailing. Frequently, and we may say usually, the change is so sudden and marked that a person standing in the open air feels it slap him with a chilling roughness, and almost immediately the moisture is dried upon him

which the preceding warmth had produced. While riding over the prairies, uncomfortably warm in the lightest clothing, I have repeatedly been struck by them, and before I could wrap my blanket around me been as uncomfortably cold. It is amusing to see with what rapidity windows are shut, clothing changed, and fires kindled when they come. Sometimes, instead of changing, the preceding wind dies entirely away, and a dead, oppressive, suffocating calm ensues, to be broken in a few hours by the wild bursts of the descending Norther.

There is no time of day, so far as I have observed, set apart for their coming. In one hundred and twenty-eight consecutive cases, sixty-two arose in the daytime, and sixty-six by night. In the year commencing October, 1859, there were fourteen by day, and twenty-two by night; the next year twenty-three by day, and twenty-four by night; the next year twenty-five by day, and twenty by night; and those occurring during this time by day seem pretty equally divided between the fore and after noon portions.

Force.

In the majority of cases the initial force of a Norther will not rise above three on the Smithsonian scale. They frequently commence faint as a summer's zephyr, again bend the trees like reeds, and I have known the brick walls of our Institute to quiver at the first striking of the blast. I have frequently been told when a high Norther struck, "It will hold like this till it is done;" but my observations fail to confirm the statement. They die down in a few hours to a force of about two, hold at this rate perhaps a day or so, then fade entirely away. The Northers frequently fluctuate in force during the day, decreasing toward night, swelling again in the night or the next day. The following examples will give a pretty fair illustration of their phenomena and changes: —

Feb. 5, 1860. Norther began in forenoon; very gentle; lasted all day and the next; dying out on the 6th at about 9½ P.M.

Feb. 9, 1860. Norther began between 5 and 6 A.M.; increased in force until it blew full four; held at that rate all day; next morning was between one and two; increased during the day to a force of three, dying down toward night; blowing next morning with a force of about one, and veering at 9 A.M. to west.

March 3, 1860. Norther began at 10½ A.M.; wind before S. W. three; changed suddenly to N. three; died down at 4 P.M.

Jan. 26, 1863. Norther began in night before, blowing in morning with a force full three; increased during forenoon; died down in afternoon; next morning was hardly perceptible; increased in forenoon; decreased in afternoon; and changed in night to a south wind.

The wind in a Norther is not always strictly from the north; it frequently veers for a few hours to N.E. or N.W., or back and forth between these points, and I have known it to give way completely for an hour or two to a southerly wind. This veering and changing, however, seldom occur in the early stages, or in a Norther of high degree.

Duration.

It is often difficult to fix the duration of Northers. *First.* They may commence or end in the night. *Second.* The regular hours of observation were 7 A. M., 2 and 9 P. M. Suppose at 7 A. M. the wind was S. 1, and at 2 P. M. was N. 1, — query, "When did the Norther begin?" The commencement of the severe ones occurring in the daytime can be told, but if they fade away when do they end? Again, when does a north-east or a north-west wind become a Norther, or cease to be one? Again, as stated, a Norther occasionally gives way to some other wind; suppose one of these interpolated winds occurs at the time of observation, shall we call it *one* Norther with varying winds, or several with intervals of from one to six hours? I have considered it one Norther from the time I detected a regular north wind until it became a settled one south of the east or west points; and in this way have found they last from one hour to six or seven days. Thirty per cent. are less than twelve hours in duration; fifty per cent. do not last over a day; and less than eight per cent. continue over three days. The longest period occurs about Christmas, and is worthy of special note, as it is the only one of sufficient length and intensity to be of service. It comes from the 24th to the 28th of December, lasts from three to seven days, and with the cold spell that follows constitutes a little winter, in which the people can lay in their supply of meat. All hands are waiting for it, — guns, pistols, knives, are ready; and as soon as the first regular blast is felt you hear shouts and squeals in every direction.

Interval.

It is a commonly received notion that the Northers return once a week, but my observations fail to confirm it. From Oct. 1, 1859,

to the last Norther in the following June, we have thirty-eight Northers in two hundred and sixty-six days, or a return of exactly once in seven days; in the following year a return of once in six and three-eighth days; and in the next, of once in six days. These yearly averages would seem to give a period agreeing with the popular notion; but what are the actual intervals? In October, 1859, they were respectively 7, 10, 8, 16 days. February, 1860, they were 4, 4, 4, 5, 5, 4 days. November, 1860, they were 2, 9, 3, 4, 4, 4, 3, 2 days. These actual intervals bear but slight resemblance to the yearly average. The general average, therefore, can be of no use in ascertaining the probable interval between them, and of little in ascertaining the physical law producing them. The interval elapsing from the end of one to the commencement of the next is even more irregular than the numbers given; and I cannot find any relation between the severity of a Norther and the interval that precedes or follows it.

Number.

The total number of Northers in a year varies from thirty-five to forty-eight; the average is about forty-two or forty-three. We are told they commence the last of September and end in May; but meteorological observations show they commence earlier and end later; in fact, that there is no month in which they may not occur. The discrepancy between fact and the common idea doubtless arises from the harmless nature and refreshing character of the wind during the summer months. In 1860, there were two in June, and one in August; there was no north wind or barometric substitute for it in July that year. In 1861, a Norther, having a force of five, came up suddenly at 2 P.M., the 11th of June, and lasted the rest of that and the whole of the next day. In 1862, there were several in June, one having a force of three, and lasting four days, another lasting two days; in July, one; August, one; September, three; Oct. 9th, one came, lasted five days, gave a frost on the 11th, and was said by the citizens of our place to be "the first Norther of the season," — with what meteorological accuracy we have seen. In July, 1863, there was one; in August and September, two each. In July, 1864, one; in August, two. The conclusion, therefore, is that they may occur every month; but the intervals are longer, and the winds less marked, from the first of June to the last of September; while from October to June they occur within intervals of from two to sixteen days, having a yearly average of forty-two or forty-three.

Thermometric Phenomena.

The thermometer usually falls during a Norther, though I have a few cases recorded in which it has risen. These exceptional cases I attributed to the Norther's clearing away the clouds of a preceding storm. The thermometer frequently falls rapidly at their commencement,—it is said, sometimes seventy degrees in fifteen minutes; but I have never witnessed such rapid or extreme falls. The greatest I have noted is twenty degrees the first hour and fifteen the next, making thirty-five degrees in two hours; and this is a very exceptional case. In the following cases the actual fall is given from the last recorded observation preceding the Norther to the first one after it began: October, 1859, the fall was 5°, 7°; November, 16°; December, 35°, 17°, 7°, 4°, 20°; January, 1860, 0°, 12°, 25°, 4°; February, 4°, 10°; March, 0°, 10, 1°, 3°, 0°,—making an average of ten degrees to the Norther. In Northern Texas there is always a great fall in the thermometer from 2 to 9 P.M.; and if a Norther commences in the afternoon it is questionable how much is owing to its presence. I have, therefore, in the above cases omitted all that began between 2 and 9 P.M. If we take all that occurred from October, 1859, to last of June, 1860, the general average would not materially differ, being ten and one-ninth degrees. The average for December, 1864, was seventeen degrees; that for the year from October, 1864, to June, 1865, was thirteen degrees. Small as the thermometric fall appears in figures, the Northers are frequently accompanied by frost out of season, and on this account are dreaded by all.

Barometric Phenomena.

Usually the barometer commences falling from two to six days before a Norther sets in, and drops down slowly, but pretty regularly, until the first stroke of the Norther, when it rises rapidly. Frequently the fall is more rapid just before the change; and I have often been led to the belief that a Norther was close at hand by this phenomenon, in the absence of the other usual indications, and I do not remember ever being disappointed. And the almost invariable fact that it rises the moment one begins has sometimes been my first and surest evidence that one is blowing. Frequently the rise during a Norther is greater than the normal height, or that reached in the preceding interval. The following taken at random will give an idea of these changes, the height being reduced to the

freezing point: Nov. 11, 1859, preceding fall, 0.488, rise, 0.933; Jan. 11, 1860, the fall was 0.129, rise, 0.111; on the 26th the fall was 0.190, the rise, 0.510; Oct. 7th, 1863, the fall was 0.337, the rise, 0.232. I have failed to detect any relation between the severity or continuance of a Norther, and the amount of the barometric fall before or rise in it.

Peculiar Phenomena.

Kinds. — The Northers may be divided into two classes, — the Wet, or those accompanied by rain, sleet, or snow; and the Dry, in which the sky is clear, or but partially covered with clouds. If the preceding wind has been east of south, we usually look for a Wet Norther; if it has been directly south, the sky laden with clouds, and the Norther does not scatter them immediately, it may be Wet; if the wind has been west of south, it is usually a Dry Norther. This I attribute mostly to our position in relation to the Gulf. As the prevailing winds are a little west of south, by far the greater part are Dry, and if not sufficiently cold to freeze the little bodies of surface water speedily evaporate them. It is a curious fact that the air constituting a Norther seems to be utterly divested of water. Even the wet ones do not bring their moisture with them, but derive it from the already laden air. If there are any clouds floating, a Dry Norther is occasionally ushered in with a dash of rain; but in this case the Norther commences suddenly, and with considerable force.

Depth. — The Northers are mere surface winds. When the wind is ranging from three to five the clouds, and even down, are frequently seen floating in the opposite direction. The gusts of wind sometimes seem to actually roll along the ground.

Ozonic Nature. — The Northers, usually the Dry ones, are frequently ushered in or accompanied with a peculiar smoky smell; sometimes a whitish curdling of the air; occasionally a peculiar, dry, fog-like appearing substance drifts along the surface of the earth, scarcely ever over ten or fifteen feet in height. The smell and appearance do not resemble those of burning grass or wood, and occur at all seasons. The curdling of the air is a peculiar feature of the Northers, and is almost indescribable. Imagine a dry, waterless fog drifting along the ground, catching in the high weeds, among the leaves of shrubbery, and wrapping around the trunks and lower limbs of the trees, of a grayish white color, and the air looking mottled, — and you have as good an idea as words can con-

vey. Suspecting the smoke and fog were connected, and ozonic in nature, I repeatedly prepared test papers, and in no case failed to get a speedy action upon them. I, therefore, attribute them to its presence.

Effect.—The effect of Northers on vegetation and disease is like what we would expect from an ozonic air. If it is a dry one, vegetation wilts during its continuance, as if it were subjected to a drouth, and only the shortness of a Norther saves it from suffering. Low or typhoid fevers are benefited by them more than can be attributed to the cooling of the atmosphere; colds are rarely produced by them, even in exposed cases; and consumption is scarcely heard of in the regions where they prevail. In fact, whether attributable to them or other climatic influences, persons afflicted with asthma or consumption seem to get a new lease of life by moving to those sections.

Heralds.—A warm moist wind blows from some southerly quarter a few days; the thermometer rises; the barometer sinks slowly, then rapidly; the wind materially slackens, veers to the west, or gives way to a dead, oppressive calm; and, lastly, a peculiar dark cloud-like appearance forms in the north or north-western horizon, slowly rises, and when in a few hours it reaches an angle of thirty or forty degrees the Norther bursts upon us.

Attendants.—Usually the immediate rise of the barometer and falling of the thermometer; sometimes a dash of rain; occasionally the ozonic smell and curdling of the air; almost invariably the rapid disappearance of the northern cloud-like formation; and frequently so great a reduction of temperature that a frost or freezing occurs out of season.

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3. Description of an Arctic Tide-Gauge. By John M. Batchelder, of Cambridge, Mass.

This instrument is intended for registering the height of the tide at stations where the float and box commonly used are liable to be obstructed by ice.

A strong iron tube, about four inches in diameter, is firmly bolted to a wharf or pile. It is open at the top, and has at the lower end a nipple to which an India-rubber bag is fastened,—the length

of the tube being sufficient to allow the elastic bag to be always submerged at the lowest stage of the tide.

The bag is supported by a suitable shelf, or cage, and is filled with glycerine, which is poured in at the top of the tube. When in this condition the glycerine rises and falls within the iron tube in proportion to the varying height and pressure of the column of water above the rubber bag, the difference in the height of the two columns being in proportion to the difference of the specific gravity of the water and the glycerine. The parts above described insure protection from floating ice, and prevent congelation within the iron tube.

A copper tube, about three inches in diameter, closed at the bottom, and open at the top, is placed within the iron tube, and floats in the glycerine: if left free it would rise and fall with the changing level of this liquid. The length of the central tube is a little greater than the whole range of the tide.

Near the upper end of the outer tube, there are three spiral springs, fixed at the top and united at the bottom by a plate or disk, from which the central copper tube is suspended. From a stem fixed to the centre tube or float, and moving with it, a string or chain leads over a single pulley, and gives horizontal motion to the pencil carriage of the recording apparatus.

The distance that the central tube is to move, vertically, is adjusted to agree with the required range of the pencil upon the record paper, by placing within it suitable weights.

As the glycerine rises or falls in the annular space between the iron tube and the central float, the spiral spring at the top is more or less extended, the extension being uniform on account of the cylindrical form of the float.

It is not necessary that the India-rubber bag be enclosed in a perforated box for the purpose of preventing oscillation; as it is always submerged, and the pressure upon it is equal to the weight of a column of water, having its base at the bag, and its summit at the mean level of the surface waves.

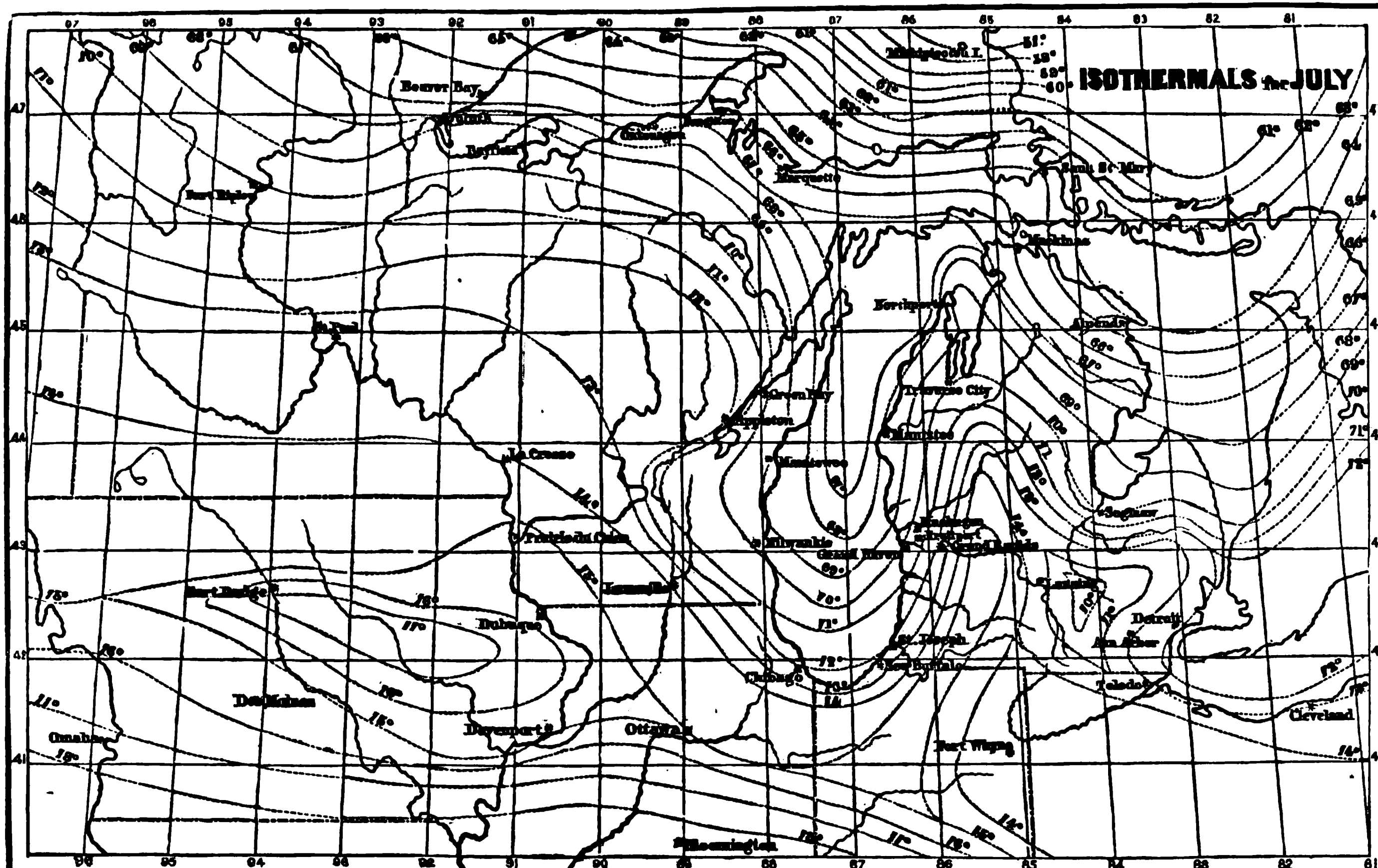
This instrument has been constructed by the United States Coast Survey, and is now in operation at the tidal station in the Boston Navy Yard.

4. The Isothermals of the Lake Region. By Alexander Winchell, of Ann Arbor, Michigan.

It may be remembered that four years ago, at the Buffalo meeting of this Association, I read a paper on the "Fruit Belt of Michigan," in which I presented some statistics, illustrating the influence of Lake Michigan upon the climate of the contiguous regions on the east side. More recently I have had occasion to continue my investigation of the climatology of the Lake Region, and to prosecute it to a much greater degree of thoroughness and detail. For this purpose I have accumulated all the meteorological observations ever published from within the limits of the State of Michigan, as well as many observations yet unpublished. For purposes of comparison, I have collected similar *data* respecting more than fifty selected localities lying outside of the State of Michigan. The Michigan observations aggregate two hundred and eighty-four years, and those of the other localities four hundred and ninety-three years. The result of this discussion is to establish from extensive inductive *data* the existence of very remarkable influences exerted by the great lakes upon the temperature of the regions adjacent. A general statement of these results is here presented.

For the purpose of exhibiting the thermometric generalizations to the eye, I have constructed nine isothermal charts, covering the area between the fortieth and forty-eighth parallels of latitude, and between the eightieth and ninety-seventh meridians. This embraces the region within the influence of Lakes Superior, Michigan, and Huron, and the valley of the Mississippi as far west as Kansas and Nebraska.

It is well known that these great bodies of water exert a cooling influence in summer, and a warming influence in winter. The isothermal charts for July and January, to which I direct your attention, present these influences in strong contrast. Turning our attention first to the chart for July, we are at once impressed by the magnitude of the deflections of the isothermals in passing the great lakes. These deflections are toward the south, in consequence of the cooling influence of the lakes. In the lower peninsula of Michigan the lines all form loops opening southward, showing that the mean temperature of July, in the interior, is much higher than along the lake borders. And yet, within the peninsula


ISOTHERMALS for JULY
Beaver Bay
Duluth
Bayfield
Marquette
Sault St. Mary
Mackinac
Northport
Alpena
Traverse City
Green Bay
Appleton
Manitowoc
La Crosse
Milwaukee
Grand Haven
Grand Rapids
Saginaw
Detroit
Ann Arbor
Toledo
Cleveland
Dubuque
Davenport
Des Moines
Omaha
Ottawa
Chicago
St. Joseph
New Buffalo
Fort Wayne
Bloomington

of Michigan, the isothermals do not attain so high a northern limit as in the continental region west of Lake Superior. The isotherm of seventy degrees, for instance, first appears within the limits of the chart in the latitude of forty-eight degrees in the valley of the Red River of the North. Passing south-eastward and eastward to the valley of the Menominee River, it comes within the influence of Lake Michigan, and bends directly southward through Green Bay and Milwaukie to latitude 42° 40′, and thence trends northward to Traverse City in latitude 44° 40′. Here it is deflected southward again under the influence of Lake Huron, and, passing Saginaw and Sanilac, finally bends north-eastward to attain its normal position, striking Penetanguishene on Georgian Bay of Lake Huron. West of Lake Michigan, this isotherm sweeps across a latitudinal belt of five and a half degrees. Within the peninsula of Michigan, it is deflected first northward two degrees, and then southward one and a half degrees.

Similar deflections are experienced by the isotherms between 67° and 72°. The isotherms of 73°, 74°, and 75°, appear to escape much of the influence of Lake Huron. The isotherm of 74° divides in Southern Michigan, — one branch passing eastward through Northern Ohio, and the other southward through Central Indiana and Southern Ohio. The State of Ohio consequently constitutes an area of uniform temperature in July, which is identical with the mean temperature of Central Michigan to the limit of four and a half degrees of latitude, or three hundred miles, further north.

An area in the south-eastern part of the peninsula of Michigan seems to be an area of cold; since the temperature is two or three degrees colder than it is on either side. There exists a region in this part of the State which is topographically elevated about three hundred feet above the general level of the peninsula. It is the region of outcrop of the sandstones of the Marshall Group, but it is not entirely coincident with this area of cold. An area of warmth seems to be indicated in Northern Iowa.

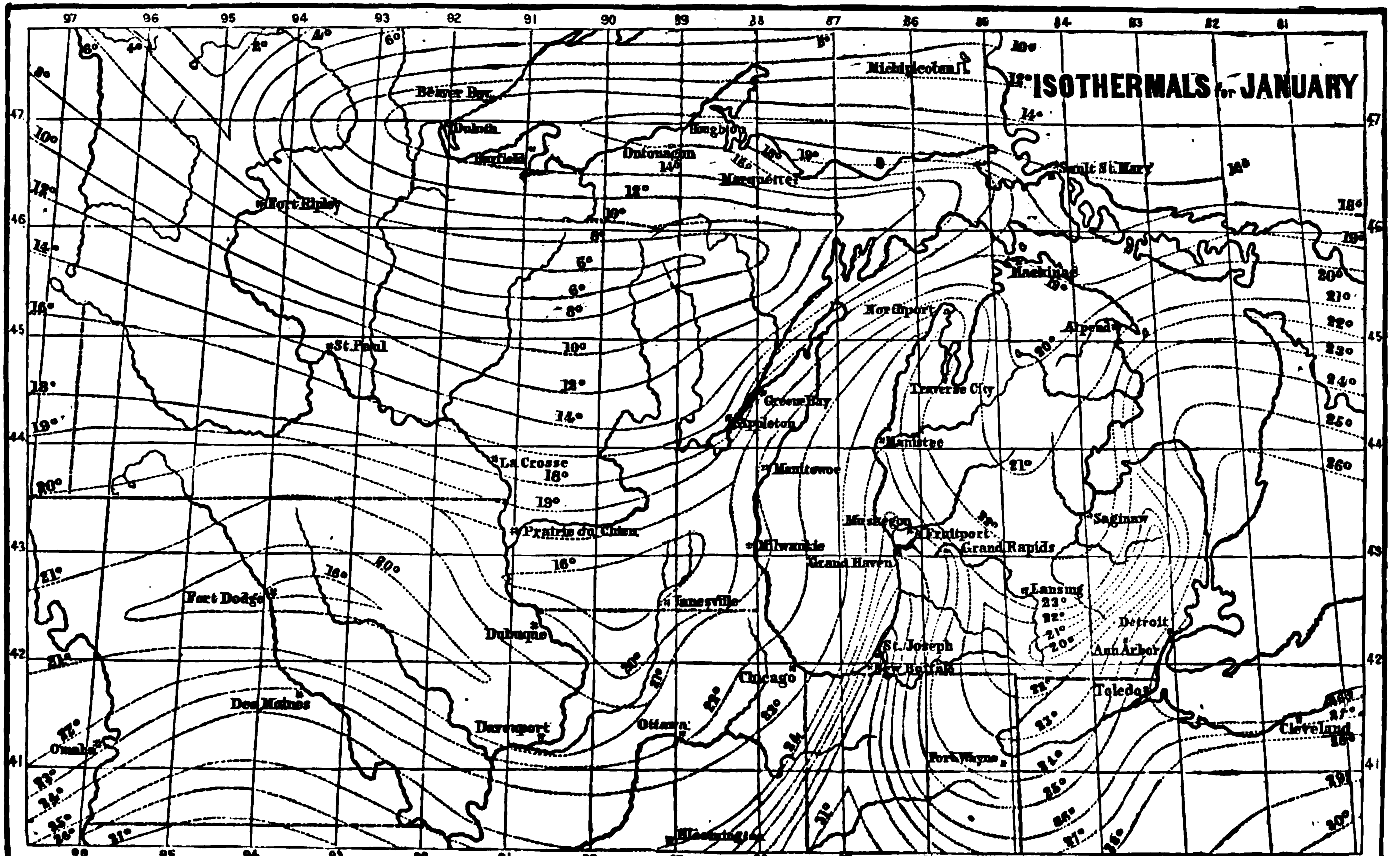
It will be observed that the cooling effect of Lake Michigan is somewhat greater on the west side than on the east. Not only are the isotherms deflected from a higher latitude on the west side, but they likewise attain a somewhat lower latitude. The lowest deflection of the curve of 75°, for instance, is at Ottawa, Ill., to the west of the meridian of the lake. The curves of 71° and 72° are also somewhat more southern on the west side than on

the east. This circumstance is undoubtedly accounted for by the slight preponderance, during July, of winds from the east of the meridian. Thus, at Chicago, this preponderance is as 60 : 33 = 1.82; at Milwaukie, as 48 : 37 = 1.30. But at Milwaukie, and further north, northerly and even north-westerly winds feel the influence of Green Bay.

Contrasting with these results those represented on the isothermal chart for January, we are at once struck with three phenomena: 1st, the great deflection of the isothermal lines; 2d, their northward deflection; and 3d, the exertion of an excessive amount of lake influence upon the east side. All this is illustrated by tracing the isotherm of 22°. Coming within the limits of the chart, a few miles south-west of Omaha, it pursues an undulating course eastward to Ottawa, in Illinois, when it bends abruptly northward, passing west of Chicago, and east of Milwaukie, to Northport, at the mouth of Grand Traverse Bay, whence it bends southward to Corunna, in the middle of the lower peninsula of Michigan, and northward again to Thunder Bay Island of Lake Huron, and thence east to Penetanguishene on Georgian Bay. The isotherm of 23° reaches almost as far north; but, in crossing the peninsula of Michigan, it strikes southward into Northern Indiana and Ohio, thence northward again almost to Thunder Bay Island. The sinuosities of this isotherm spread over a belt four and one-half degrees, or three hundred miles in width. In other words, the influence of the lakes is such that the mean temperature of January at Northport and Thunder Bay Island is identical with that of Omaha, Peoria, Chicago, and Fort Wayne. The January temperature of Mackinac and Marquette is the same as that of Green Bay and Fort Winnebago.

An island of cold is again indicated in the south-eastern part of the peninsula of Michigan. In this case its form and position correspond quite exactly with a region of elevation. The area in Northern Iowa, which in July is an island of warmth, appears to be in January an island of cold. A similar one exists in the elevated region of Southern Wisconsin, while a remarkable axis of cold stretches through Northern Wisconsin and Minnesota. This axis is not entirely coincident with the crest of the ridge dividing the tributaries of Lake Superior from those of the Mississippi; since the warming influence of Lake Superior crowds it about sixty miles southward.

One of the most striking phenomena exhibited by the chart for


ISOTHERMALS for JANUARY
Michipicoten I.
Beaver Bay
Duluth
Bayfield
Ontonagon
Houghton
Marquette
Sault St. Mary
Fort Ripley
St. Paul
Mackinac
Northport
Alpena
Traverse City
Green Bay
Appleton
Manistee
La Crosse
Manitowoc
Saginaw
Muskegon
Fruitport
Grand Rapids
Prairie du Chien
Milwaukie
Grand Haven
Lansing
Janesville
Fort Dodge
Dubuque
Detroit
Ann Arbor
St. Joseph
New Buffalo
Chicago
Toledo
Des Moines
Davenport
Ottawa
Cleveland
Omaha
Fort Wayne
Bloomington

January is the excess of the warming influence along the eastern side of Lake Michigan. The isotherm of 23½° strikes from Chicago directly to Northport, almost at the opposite end of the lake. The contrast in January temperature between the opposite shores of the lake is, for the northern half, four degrees, and for the southern, six degrees. This circumstance is due to the fact that the cold winds of the region come from the west and south-west. The precise ratios of the winds from the east and the west of the meridian in January are at Chicago, according to eleven years' observations, as $72 : 5 = 14.4$; at Milwaukie, for thirteen years, as $60 : 18 = 3.33$; at Manitowoc, for eleven years, as $67 : 11 = 6.09$. These results embody all January winds, except those directly from the north or south. The reason why the excess of warming influence on the east side is greater toward the south than toward the north is evidently because north, and even north-west, winds coming from Green Bay add their warming effect to that of Lake Michigan in all the region north of Milwaukie.

The isothermal charts for the summer and winter contrast in the same way as those for July and January. From the summer chart we perceive that the isothermal of 72° makes its advent upon the northern limit of the chart, and disappears upon its southern limit only 12° of longitude further east. Coming from the Winnipeg country, it passes near Dubuque and Ottawa, thence into the centre of the peninsula of Michigan. Sweeping around this region, it strikes directly south to Germantown and Portsmouth, in Ohio. The summer temperature of the Winnipeg region, and of Central Michigan, is identical with that of Northern Illinois and Southern Ohio. Areas of cold exist in South-eastern Michigan and Northern Minnesota; and large areas of uniform temperature in Wisconsin, Indiana, and Ohio.

The excess of cooling influence upon the west side of the lake, during the entire summer, is quite noticeable. The isothermals, in approaching the Lake Superior region, make an angle of 45° with the meridian; and under the influence of Lake Michigan they become quite parallel with the meridian. It does not appear that, in the Lake Superior region, any excess of winds from the lake exists; but, in the vicinity of Lake Michigan, such excess is well established. At Chicago, the winds from the lake are to those from the land, during summer, as $151 : 119 = 1.27$; at Milwaukie, the lake winds are to the land winds as $142 : 104 = 1.27$; at Manitowoc, the lake winds are to the land winds as $153 : 123 = 1.24$.

From the winter chart we notice that the isotherm of 24° undulates over a breadth of more than two hundred miles. Other isotherms are similarly sinuated. The mean winter climate of Mackinac is 20°; and is identical with that of Green Bay, Fort Winnebago, and Fort Dodge.

The excess of the warming influence on the east side of Lake Michigan is most apparent. The winter mean of Chicago is 24⅓°, while that of New Buffalo, in the same latitude, is 28°. The winter mean of Milwaukie is 22°, while that of its *vis-à-vis*, Grand Haven, is 26°. The winter mean of Fort Howard is 20°, and of Appleton, 19°; while that of Traverse City, farther north than either, is 23⅓°. These contrasts illustrate again the effect of the prevalence, during the cold season, of winds from the west of the meridian.

As to the isothermals for the spring and autumn, it might be expected that they would suffer little deflection under the influence of the lakes. Comparatively speaking, this is the case; but it will be noticed, nevertheless, that a marked cooling influence is exerted in spring; since the isotherm of 43°, for instance, is deflected southward one hundred and fifty miles. It is worthy of remark at the same time, that the maximum deflection takes place on the west side of Lake Michigan. On the east side, the deflection of the same isotherm amounts to no more than twenty miles. In general, we find the mean spring temperature of the eastern side of Lake Michigan to be about three degrees higher than the mean spring temperature of the western side. As this excess is accumulated in April and May, — especially in May, — it is at once apparent that the circumstance has a most important bearing upon the growth of spring crops on the opposite sides of the lake. The effect is such that the temperature of Grand Haven, March 15, is equal to that of Milwaukie, March 21; that of Grand Haven, April 15, is equal to that of Milwaukie, April 24; that of Grand Haven, May 15, is equal to that of Milwaukie, May 28. These contrasts relate to *mean* temperatures. They show that vegetation on the east side secures a start of six to thirteen days. Add to this, protection from *exceptional* cold, in the form of spring frosts, and, to this, the effects of a drier and lighter soil, and we get a clear and demonstrative explanation of the difference in the agricultural and pomological products of the opposite sides of the lake.

This contrast of temperatures in spring is explained, as before, by the predominance, during the cold month of March, of winds

from the west of the meridian, and during the warmer months of April and May, of winds from the east of the meridian. Thus, at Manitowoc, in March, the winds from the west of the meridian are to those from the east as 43 : 24 = 1.8; at Milwaukie, they are as 44 : 32 = 1.4; at Chicago, as 57 : 20 = 2.85. On the contrary, the preponderance of winds from the east of the meridian during May is, at Manitowoc, as 37 : 26 = 1.42; at Milwaukie, as 62 : 24 = 2.58; and in April, as 52 : 33 = 1.6; at Chicago, including north winds, which are here lake winds, the ratio of lake and land winds, in May, is as 44 : 40 = 1.1.

In autumn the resultant of the lake influences on the west side is almost zero; while, on the east of Lake Michigan, a warming effect is experienced, amounting, along the southern half of the lake, to one or two degrees, and, along the northern half of the lake, to three or four degrees. This, as before, is caused by a preponderance, during each of the autumn months, of winds from the west of the meridian. This preponderance is shown for Chicago by the ratio of 151 : 70 = 2.16; for Milwaukie, by the ratio of 147 : 94 = 1.56; and for Manitowoc, by the ratio of 160 : 60 = 2.67.

The advantages thus secured to vegetation along the east side of the lake are not less in autumn than in spring. These singular facts depend upon a shifting of the prevalent winds at the end of the cold season, toward the close of March, and again at the end of the mild season near the close of November. An investigation of the monthly means on the opposite sides of the lake, during autumn, shows that the temperature attained at Milwaukie, Oct. 15, is not reached at Grand Haven until Oct. 20. The Milwaukie temperature of Nov. 15 is only reached at Grand Haven Nov. 23. Comparing Chicago and New Buffalo, we find that the Chicago temperature of Sept. 15 is the same as the New Buffalo temperature of Sept. 21. The October and November temperatures seem to be nearly coincident. These comparisons show that the warm season is lengthened, on the east side, about six to eight days in the autumn. This, added to the time gained in the spring, makes the growing season, on the east side of Lake Michigan, from twelve to twenty-one days longer than on the west side, — to say nothing about exemption from unseasonable frosts and a much warmer constitution of the soil upon the east side.

Turning our attention now to the chart of isothermals for the year, we might anticipate that the warming and cooling influences of the lakes would exactly neutralize each other, so that the iso-

thermals would experience no deflection. We find, however, that on the western side the resultant influence is slightly cooling, and on the eastern side decidedly warming. The resultant of these two influences gives a final resultant of a warming character exerted upon the eastern side. This final resultant has a value of one-half to two degrees. In other words, Lake Michigan elevates the mean annual temperature of the contiguous region nearly two degrees above the norm. This results, of course, from the fact that the mean temperature of the lake waters is higher than that of the land. This excess must be considerably greater than the resultant warming influence upon the land. Its explanation is a curious and interesting subject of inquiry. It cannot be caused, as in the case of the Gulf Stream, by great currents moving from tropical regions. Nor can we attribute it to a large volume of river water poured into the lake from regions lying to the southward. Some more occult cause operates to raise the mean temperature of the lake above the normal temperature of the land.

I suspect that the mean temperature of the tributary streams of the lake is somewhat above the atmospheric mean of the year. The greatest volume, perhaps, is poured into the lake during the milder months; but more than this, the waters of the tributaries, by the laws of physics, can never be cooled below a certain limit, while their warming may proceed to the extreme limit of the atmospheric temperature. The same considerations will apply, to some extent, to the shallow bays connected with the lake. Still, I conceive, there must be another cause invoked for the full explanation of the phenomenon under consideration.

I do not hesitate to suggest that this cause may be the internal heat of the earth. Consider the depth to which the basins of the great lakes are excavated. Lake Michigan has a mean depth of nine hundred feet. At this depth in the solid crust of the earth, we should expect to find the temperature some eighteen degrees above the mean temperature at the surface. That is, if the mean land temperature, in the middle latitude of the lake is 44°, the temperature of the lake bottom should be 62°. This heat received from the bottom, however, would be distributed through the whole mass of lake water, so that the average temperature of the mass might not be increased more than nine degrees.* The excess of radiation from the warmer waters of the lake might reduce the

* It is probable that the temperature at or near the bottom is considerably lower than that near the surface.

warming effect of the lake bottom to four or five degrees, in the whole mass of water. It may not be amiss to mention, also, that the lake waters at the depth of nine hundred feet, in consequence of the mingling of the temperatures of the different strata, would be cooler than the land at the same depth. But as the bottom immediately underlying the water must possess nearly the temperature of the water, it is evident that the warming effect upon the water is less than eighteen degrees as first calculated. Still we must argue that the rate of increase of temperature at greater depths beneath the lake would be more rapid than at the same depths upon the land, so that the actual resultant warming influence exerted upon the lake waters at the bottom would be somewhere between the two results already indicated. It would be a positive warming effect, and its reaction upon the temperature of the land would be very nearly such as indicated by our isothermal lines for the year.

In studying the influence of the great lakes upon the climate of the contiguous regions, we should especially note its presence under circumstances of exceptional cold or heat upon the land. For the purpose of illustrating these relations, I have constructed two isothermal charts for minimum temperatures. One of these is a chart for *mean minima*, and the other a chart for *extreme minima*. By the "mean minimum" of a locality, I understand the *average* of the yearly minima for a series of years; and by the "extreme minimum," the *lowest point* attained during that series of years. These charts present results which are truly striking. The isotherms in the vicinity of Lakes Huron and Michigan trend literally north and south. In the chart of mean minima the isotherm of —15° strikes from Mackinac through Manitowoc, Milwaukie, and New Buffalo, to Fort Riley, in Kansas, near the parallel of 39°. Here is a deflection over nearly seven degrees of latitude, or about four hundred and eighty miles in a straight line. The meaning of this is, that the most excessive cold at Mackinac, for a period of twenty-eight years, is not, on the average, greater than at Fort Riley, four hundred and eighty miles further south. It is one degree less than at Chicago for a term of eleven years. By a glance at the chart of extreme minima, we perceive that the lowest point reached at Mackinac is but two degrees lower than the extreme minimum of St. Louis. Extreme weather of Chicago is twelve degrees colder than at New Buffalo. The lowest extreme of Milwaukie is fourteen degrees below the extreme minimum of

Grand Haven, while the extreme of Fort Howard is twenty degrees below that of Northport. In general, while the mean minimum along the west side of Lake Michigan is —16, that along the east side is —6; while the extreme minimum on the west side is —22° to —30°, that of the east side is —10° to —16°.

I cannot forbear directing attention to the important bearing of these additional facts upon the results of soil cultivation. It will be remembered that it is not the severity of the winter mean, but that of the winter *extremes*, which conditions the immunity of exotic plants from destructive frost. One killing freeze is as fatal as thirty. That one killing freeze is as likely to occur at Fort Riley, or Leavenworth, or Peoria, or even St. Louis, as at Mackinac. The whole east shore of Lake Michigan is 15° to 20° more secure than any of the places just named. As grapes and peach-trees require for their destruction a temperature of —20°, it is apparent that peach orchards and vineyards are perfectly secure along the whole extent of the eastern shore of Lake Michigan.

The *rationale* of these remarkable climatic effects is not difficult to discover. It lies in the comparatively low capacity of watery surfaces for absorbing and radiating heat. The mean temperature of the land in the middle latitude of Lake Michigan is about 44½°, and that of the lake a few degrees higher. In July the temperature of the land rises to 74°, while that of the lake is not above 51° or 52°. This difference is partly due to the fact that upon the land the heat from the solar rays is accumulated near the surface, while upon the water it is disseminated through the whole mass by the action of waves and currents. In January the mean temperature of the land sinks to 19°, while that of the water does not, probably, fall below 40°. The atmosphere in contact with the water must partake to some extent of the temperature of the water, and, when moving from the water to the land, must transfer to the land some portion of the heat or cold proper to the lake. The effect is a tendency to equalize the land temperatures. This tendency is most distinctly felt in case of extreme weather. On occasion of our coldest weather, the wind blows generally from the south-west, and, passing diagonally over Lake Michigan for a distance of one hundred to two hundred miles, must necessarily experience a great degree of amelioration.

The influence of the sea in equalizing temperatures has long been understood. The immunity from unseasonable frosts secured by bodies of fresh water to localities in their immediate vicinity

has also been universally observed; but the fact that inland lakes, of the size of Lake Michigan, exert an ameliorating agency, quite comparable with that of the Atlantic Ocean, is something which has only been brought to light by recent thorough discussions of a wide range of meteorological *data*. On general principles, it has, indeed, been asserted by Professor Henry, and by Blodgett, and at an earlier period by Humboldt, that the great lakes of North America must exert some influence in deflecting the isothermal lines; but when we come to examine any of the charts which have been published to represent existing knowledge or conceptions, we fail to detect any marked inflection of these lines in passing the region of the great lakes. In fact, the thermometric observations from the fifty-five meteorological stations in Michigan have not heretofore been employed in tracing out the remarkable tortuosities of the isothermals of the lower peninsula of Michigan. I believe these disclosures are destined to take their place among the most remarkable phenomena of climatological science.

NOTES. — The views set forth in the foregoing paper were first foreshadowed in a report on the "Grand Traverse Region," published in 1866. They were again published with a few additions in the Proceedings of this Association for 1866. In 1867, I received from Dr. I. A. Lapham a chart of Wisconsin, bearing date 1865, in which the isothermals for January and July are shown to be extensively deflected in Wisconsin by the influence of Lake Michigan.

I desire to express my thanks to J. F. Grant, Esq., for a full transcript of his meteorological observations at Traverse City, and to General W. F. Raynolds, Superintendent, and C. F. Henry, Assistant, for permission to copy the unpublished results of the observations of the Lake Survey.

VI. CHEMISTRY AND MINERALOGY.

1. A Graphical Discussion of the Various Formulæ proposed for the relation between the Quantity of Light produced by the Combustion of Illuminating Gas and the Volume of Gas consumed. By Frederick E. Stimpson, of Boston, Mass.

[Abstract.]

I found upon examination that three formulæ had been proposed for this reduction, namely: —

(1). The common one, $\frac{l}{l'} = \frac{g}{g'}$, which is expressed by saying that the light (l) is proportional to the quantity of gas (g) consumed.

(2). That proposed and used by Bunsen and Roscoe, p. 884, Vol. 149, Phil. Trans., 1859, $\frac{l-l'}{l'-l''} = \frac{g-g'}{g'-g''}$, which is expressed by saying that for a given flame the increase of light is proportional to the increase of the quantity of gas consumed.

(3). And, finally, Farmer's formula, proposed by Professor Silliman at the Salem meeting of this Association, $\frac{l}{l'} = \frac{g^2}{g'^2}$, which is expressed by saying that the light is proportional to the square of the consumption.

These three formulæ transformed so as to express the value of l become: —

$$(1\,b.)\ l = \frac{l'}{g'}\,g, \text{ or } l = Ag.$$

$$(2\,b.)\ l = \frac{l'-l''}{g'-g''}\,g - \frac{l'-l''}{g'-g''}\,g'', \text{ or } l = Ag - B.$$

$$(3\,b.)\ l = \frac{l'}{g'^2}\,g^2, \text{ or } l = Ag^2.$$

I have collected from various publications upward of one hundred and twenty independent series of determinations of the relative illuminating power of gas consumed at various rates from different burners. These burners comprised single jet, union jet or fishtail, slit or batswing, and Argand; and each set contained from two to ten single determinations. These series, together with some of my own determinations, were represented in the form of

curves, and by means of the magnesium lantern, projected on the screen for inspection.

From the results of observations thus far made, I conclude that Bunsen & Roscoe's formula (a straight line cutting the axis g) would represent the greatest number of series, and particularly the series belonging to the Argand burners.

That for those series belonging to the jet, the fishtail, and bats-wing burners, the common formula (a straight line passing through the origin, which is a modification of Bunsen's, in which $B = 0$) very closely represents the relation found by experiment.

Whereas the number of cases in which the series, or any considerable part of the series, could be represented by a parabola (formula No. 3) were very few.

I found, however, that when a gas flame was on the verge of its smoky condition, a tangent to the curve would almost always pass through the origin, showing that, for a limited range of consumption at that point, the light is proportional to the consumption.

One other point was also very apparent: that such is the influence of the burner upon the flame, in order to get the best result for any given consumption, the burner must be adapted to that particular consumption.

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2. On the Examination of the Bessemer Flame with Colored Glasses, and with the Spectroscope. By Justus M. Silliman, of Easton, Pa.

I. *Examination with Colored Glasses.*

In the Bessemer process, the progress of the decarbonization is determined chiefly by the appearance of the smoke, flame, and sparks which are emitted from the apparatus. Owing to the rapidity with which the reactions take place, it is highly important to catch the exact moment when the blast should be turned off. This is indicated by the color and brightness of the stream of gas issuing from the converter, and by this the moment of total decarbonization can generally be accurately determined by the naked eye. When, however, pig-iron of certain qualities is used (manganiferous iron, for example) this determination is very difficult;

even those who have had much experience make frequent mistakes, and find it impossible to produce the same quality of steel at every blow.

In order to intensify these flame-indications, use has been made of the spectroscope, and also of various combinations of colored glasses. The former was first attempted by Dr. Roscoe, and the latter by Mr. Rowan at the Atlas Works.

Mr. Rowan experimented with a great variety of colored glasses, and obtained the best results by using three glasses, two of ultramarine blue, and one of dark yellow. This little instrument, or chromopyrometer, as he terms it, is now in daily use at the Atlas Works, its indications being so marked and unmistakable as to render its use safe in the most inexperienced hands.

The following experiments were made at the Bessemer Steel Works of John A. Griswold & Co., in Troy, while pursuing the chemical course in the Winslow Laboratory of the Rensselaer Polytechnic Institute. In my observations on the flame I made use of the spectroscope, and also of a combination of colored glasses. This combination consisted of two light-yellow glasses and a blue one, through which the sunlight appeared of a deep purplish-blue tint; and as it differed slightly from Rowan's, it gave somewhat different results.

In order to reproduce the appearance of the flame at the different stages of the process, I prepared a plate consisting of about a hundred varieties of colors and tints, all of which were numbered, and thus referred to a table which indicated their composition. They were also arranged to be seen with either a light or dark background. The use of this plate was of necessity limited to daylight, but the illustration and description are given as occurring at night in order to show its illuminating power.

At the beginning of the process that which issues from the converter does not appear to be a true flame, but only an illumined stream of gas carrying with it innumerable red-hot pellets of iron. This gas has scarcely any illuminating power, extends but a short distance from the mouth of the converter, and is sometimes sheathed with a whitish smoke. Seen through the glasses the flame and sparks have a deep crimson color, the converter is invisible, and at the base of the flame is a crimson band, which continues throughout the process.

As the reaction continues, this stream of gas grows brighter and more elongated, and after a few minutes a small pointed whitish

flame appears, which suddenly increases in size. At this instant the blast-pressure falls from twenty to eighteen pounds.

When viewed through the glasses the upper part of the converter comes dimly into view, and the flame and pellets of iron appear of a lighter color, while the fragments of slag which begin to be thrown out are of a deep red. This difference in shade between the iron and slag thrown out is probably entirely owing to the lower temperature of the latter, for the reason that while the iron is discharged from the metallic bath the slag is washed up on the sides of the converter, and can be seen clinging around its mouth in a spongy mass until detached and thrown out by the blast. The greater porosity of the slag and its consequent more rapid cooling would also cause a difference of temperature.

In the second period the discharge of slag increases, and the flame is very bright and illuminating, with occasional dark streaks. Through the glasses at the beginning of this period the flame is of an ashy blue color with streaks and flashes of crimson; the edges being sometimes of a purplish hue. At this point surrounding objects are illuminated, and the converter becomes distinctly visible. A wreath of crimson is seen surrounding the flame where it strikes the chimney. By the middle of this period the crimson almost entirely disappears from the body of the flame, leaving only a slight cone at its base, and a border of greenish hue makes its appearance, and gradually grows more decided. Streaks of a dark-blue color are also seen in the body of the flame.

The beginning of the third period is scarcely indicated to the naked eye, though the flame becomes somewhat weakened, and after a few minutes shows dark streaks running through it. Through the glasses at the commencement of this period the rose-colored cone begins to expand and deepen, the greenish sheath is more decided, while streaks of dark and green are visible. After a few minutes the change becomes very rapid, a few seconds only being required to reduce the flame from rose-color to the deep crimson non-illuminating gas, as at first, and again the converter is lost to view, by which time the blast should have been turned off.

The gradual fading of the crimson from the beginning of the blow, and its deepening at the termination of the process, as well as the crimson band at the base of the flame, and the wreath of crimson surrounding the flame at the chimney, tend to confirm Mr. Rowan's views, which are, that the different shades of crimson are due to changes of temperature. The stream of gas which comes

from the mouth of the converter at the beginning of the process, being illuminated from within, derives its color from the metallic bath, the temperature of which, owing to the combustion of silicon, increases more rapidly during this period than at any other.

The crimson band at the base of the flame, and the wreath of crimson at the chimney, might also be accounted for by this theory. The flame rushing from the mouth of the converter has a tendency to create a vacuum at its base around the converter's edge, and thus to cause a wreath of flame to pass over this surface and by consequent cooling produce the crimson band. The wreath of crimson at the chimney may be also due to the cooling of the flame consequent upon deflection.

It is true we have a seeming contradiction to this theory in the rose-colored cone extending from the base at the centre, which we would naturally consider the hottest part of the flame; but, as in the flame of the Bunsen burner the hottest part is in its outer sheath, the conditions of combustion in both being similar, it is probable that that part of the flame occupied by the cone is at a lower temperature than that surrounding it.

The green streaks in the flame are most intense when the manganese spectrum is brightest; and, as the color of the flame when the spiegeleisen is added is also green, we are led to suppose them due to the presence of manganese.

On two occasions simultaneous observations were made with the spectroscope and the colored glasses; but, with the exception of that just mentioned, and the changes at the commencement and termination of the blow, no striking coincidence was noticed.

II. *Examination with the Spectroscope.*

The science of spectrum analysis is yet in its infancy, and there has been no scientific investigation, perhaps, which has been more contradictory in its results than that of the Bessemer flame. The first application of the spectroscope to the analysis of the Bessemer flame was made in 1862 by Dr. Roscoe at the works of Messrs. John Brown & Co., in Sheffield. Soon after this, it was in constant use in Brown's works for controlling the process. It was next introduced at Crewe, and from there said to have been taken to Seraing, in Belgium, in 1865.

Roscoe's account of the general appearance of the spectrum has not altogether been verified by subsequent observers. His failure to see any line beyond 80° indicates an imperfection in his

instrument. He, also, is the only one who claims to have seen the sodium line as an absorption band, or who professes to have detected the lines of nitrogen and hydrogen in the Bessemer spectrum. His spectroscope was so arranged that the spectrum of the Bessemer flame was seen in the upper half of the field of view, while the spectrum with which it was to be compared was seen immediately below. The spectrum of the flame was thus compared with the following spectra: —

1. Spectrum of electric discharge in carbonic oxide vacuum.
2. " " strong spark between silver poles in air.
3. " " " " " iron " " "
4. " " " " " " " " hydrogen.
5. Solar spectrum.
6. Carbon spectrum — oxyhydrogen blowpipe supplied with olefiant gas and oxygen.

The coincidences observed were very few, and totally failed to explain the value of the Bessemer spectrum. The lines of the well-known carbon spectrum did not occur at all, either as bright lines or absorption bands, nor was any coincidence observed between the lines of the Bessemer spectrum and those of the carbonic oxide vacuum tube. The lines of lithium, sodium, and potassium, were strongly marked and identified with certainty. He found that three fine, bright lines between *E* and *b*, shown on the plate at 66½°, 67°, 67½°, coincided with those of iron; and in place of the red hydrogen line *C*, he discovered a black band which he considered an absorption-band, and states that it is better defined in wet than in dry weather.

In Austria, Prof. Lielegg followed up this subject with great perseverance, and gave more extended accounts of the varying character of the Bessemer spectrum during the different stages of the process. His experiments were made at Gratz, where the spectroscope was afterwards used with great success in controlling the Bessemer process; but at Königshütte, where dark gray manganiferous iron was used, it was found that the indications which in other works so plainly determined the moment of decarbonization were unreliable. In this case, the lines whose disappearance is to indicate the exact point of time for ending the process disappear too soon. During the period in which the spectrum is brightest, among the glowing vapors and gases that stream from the converter carbonic oxide next to nitrogen is most abundant; and it is for this reason that the first investigator, Roscoe, expressed

himself as confident that the numerous lines of the spectrum were caused by this gas, although he could obtain no coincidence.

Brunner * states that "no part of the Bessemer spectrum is ever visible in the flame when the converter is heated for the first time after being relined, but that when the lining is not new Lielegg's group of green lines ($CO\gamma$) appears in the spectrum, which then contains also the lines of potassium, sodium, and lithium." From which he concludes that this spectrum is not to be identified with carbonic oxide, but must be produced by other constituents of pig-iron. Others state that the Bessemer spectrum is sometimes visible while the converter is being heated after a blow. I made an observation of the flame from the converter while it was being heated the first time after being relined, and obtained with great distinctness the potassium, lithium, and sodium lines, but have not, under any circumstances, detected any other lines while the converter was being reheated.

Lichtenfels, by a series of simultaneous comparisons of the manganese with the Bessemer spectrum, found the lines in the blue and green fields to completely harmonize in the two spectra. The violet manganese line, which had been seen by some, he could not detect in either of the spectra. I have never observed it, but Dr. Wedding, who has summed up the observations of others, states that he has repeatedly seen it. Its position is at 135½°.

The instrument used in my investigations was constructed by Alvan Clark, of Cambridge, and consists of an equiangular flint-glass prism, in a metallic box, into the sides of which at the requisite angles are screwed an inverting telescope with a magnifying power of six, and a tube containing the adjustable slit and lens for rendering the rays parallel; also a tube with a scale, which is placed at such an angle that it is reflected from the surface of the prism through the telescope to the eye; it can be so adjusted as to appear along the upper edge of the spectrum. I was provided with Bunsen's plates of spectra on a large scale, and, in order to adapt them to the scale in my instrument, I took the spectrum of the sun and obtained Fraunhofer's lines with great distinctness. Two characteristic lines in the solar spectrum were then noted, one of which appeared at 37°, and the other at 117°, and a space measured equal to their distance apart as given on Bunsen's scale. This was divided into eighty equal parts, and the division extended in both directions. By the application of this scale to Bunsen's, I

* Van Nostrand's Eclectic Eng. Mag., vol. i., p. 508.

found that the remainder of Fraunhofer's lines in my instrument exactly coincided with their position on his plates. The correctness of the new scale was also proved by other coincidences. By moving the prism, Fraunhofer's lines will vary slightly in their relative distances apart, but in no possible position in which I might place the prism could I obtain the sun-spectrum as given by Wedding in connection with the Bessemer spectrum; if the spectrum given by him was obtained by the use of bisulphide of carbon in his prism, that substance causes a greater variation than I had supposed.

I have recorded the results of twenty-five observations on the Bessemer flame, most of which were taken at a distance of about thirty feet from the flame, though I have stationed myself at intermediate points between that and the flame; at one time sitting so close as to be almost scorched. Nearly all my observations were made at night, and the lines obtained were much better defined than when seen in diffused sunlight.

The record of my observations was kept as follows:—Five columns were ruled, headed—

Degree.	Color.	Brightness.	Time.	Remarks.

Note was made of the dark bands as well as the bright ones, both of which were classed according to their distinctness, as very bright, bright, faint, and very faint. In the time-column was noted the number of minutes after the commencement of the blow at which the lines appear.

At the first two or three observations I attempted to make a thorough note of the changes as they occurred throughout the whole spectrum, but afterward abandoned it as utterly impossible, as at the beginning of the second period the lines come in so fast, and the changes are so rapid, that they cannot be accurately noted at the exact moment of their occurrence. I therefore confined myself to a few degrees at each observation, and by this method was enabled to note accurately, and at the exact moment of their occurrence, slight changes which might otherwise have escaped notice. Note was also taken of the changes in the general appearance of the whole spectrum during the successive stages of the process. After having made half a dozen observations, while viewing the spectrum of the flame from the converter when it was being heated for another charge, it was discovered that a movement of the eye before the eye-glass occasioned a similar move-

ment of the lines of the spectrum along the scale, on which their position could thus be made to differ more than half a degree. I have seen no notice of this in the statements of others, and it may account for some of the apparent discrepancies. Thereafter, when taking the readings of any of the lines, the position of the eye was so adjusted as to bring the sodium line exactly at 50°. Owing to the extreme brilliancy of the flame the aperture may be made exceedingly narrow, and thus the many lines of the spectrum, which with a duller light and broader gauge would be blended together, may be separated.

At the beginning of the blow, the spectrum is continuous and very faint, and generally extends from 35° to 120°, covering about three-fourths of the length attained in the second period. This increases slightly in extent and brightness until the appearance of the sodium line. This line appears at the end of the first period at the beginning of a more decided flame. It comes flashing through from one extremity to the other for an instant, and then disappears only to return the next instant in brighter flashes, which are continued for about a minute, by which time the line becomes permanently established. On one occasion the sodium line, instead of flashing and disappearing as usual, continued visible after a few seconds, and expanded and contracted in width almost isochronously until it became permanently established. The appearance of this line indicates the termination of the first period. This period I have found to vary in extent from three to seventeen minutes in blows lasting from thirteen to twenty-seven minutes. None of the other lines make their appearance in vivid flashes as does the sodium. The lithium line becomes visible three or four minutes after the first flash of the sodium. It is very faint at first, but soon becomes quite distinct, and lasts through the blow. The vivid flashing of the sodium line may be accounted for by the exceedingly small amount of sodium required to produce its spectrum — an amount not exceeding $\frac{1}{180000000}$ of a grain. The slightest momentary combustion taking place in the stream of gas from the converter would at that instant render glowing a sufficient amount of the vaporized sodium to produce its spectrum, and thus occasion the flashes so characteristic in the first appearance of that line. Lithium exists in a much smaller quantity and requires $\frac{1}{6000000}$ of a grain, or thirty times that given for sodium. By the time the lithium line is established the red potassium line at 23½°, and occasionally the violet line at 135°, appear, and the blue and green

fields become divided into bands, which are so rapidly resolved into bright and dark lines that it is difficult to note the exact time of the appearance of each. The spectrum increases to a dazzling brightness, and extends itself in both directions until it reaches from 23½° to 140°.

During the third period the spectrum becomes more brilliant, and the lines more distinct. Several new lines make their appearance in different parts of the spectrum, of which the ones at 51½°, 57°, and 67°, are well defined, while others are faint, and not always visible; some of them appearing only toward the close of the last period. In viewing the lines in the most refracted part of the spectrum, it has been repeatedly observed, both by myself and others, that these lines were more strongly marked when entering the eye at an angle than when viewed directly. That this was not imagination is proved by repeated identification of lines at the same point on the scale.

At the termination of the blow, the lines are rapidly swept away, sometimes in the inverse order of their appearance, but more generally they disappear within the space of two or three seconds, leaving a continuous spectrum as at first, though somewhat brighter. Sometimes the sodium and lithium lines are swept away with the others, and at other times they remain visible. In either case the change is very decided, and does not generally occupy more than three seconds. In the course of my observations, thirty-three lines have been detected, as given in the table below.

Some of the lines given by Lielegg I have failed to find, but have detected others not given by him.

1st Period, 23½, 35, 50, 135.

2d Period, 23½, 35, 43, 44, 44½, 45½, 46, 47½, 48½, 50, 52, 53, 56, 56½, 61½, 62, 62½, 63, 65, 66½, 67½, 70, 72, 120, 135.

3d Period, 23½, 35, 43, 44, 44½, 45½, 46, 47½, 48½, 50, 51½, 52, 53, 56, 56½, 57, 61½, 62, 62½, 63, 65, 66½, 67, 67½, 70, 72, 100, 102, 103, 105, 108, 135.

Among the dark bands detected, the most intense occurred at 44–46, 51–55, 56–58, 62–64½; others were found at 33–34½, 36½, 37½, 38½, 40, 68–72.

Many of the dark bands were crossed by bright lines.

I have repeatedly observed the dark band considered by Roscoe to be a hydrogen absorption line, but have not noticed that its intensity varied with the dampness of the weather. Whether it is

an absorption band or not can be determined by a series of observations continued through wet and dry weather. If this proves to be a hydrogen line, the Bessemer spectrum will be found more complicated than is generally supposed. It has been thought by some that the dark bands in the spectrum are absorption lines due to the cooling of the outer sheath of flame, but it is more probable that, although the pellets of iron and slag tend to produce a faint continuous spectrum, in contrast with the very brilliant lines it appears discontinuous, the dark bands being merely intervals between the bright ones. The iron spectrum has not been satisfactorily identified. It has been suggested that the brightness and size of the lines of the Bessemer spectrum do not allow the iron lines to appear. In comparing the Bessemer spectrum with Bunsen's spectra of nickel, cobalt, and calcium, no coincidences were observed except two or three in the latter spectrum. The brightest calcium line, however, was not visible in the Bessemer spectrum. The Bessemer spectrum contains yet many mysteries to be solved, among which is the cause of the non-appearance of the lines of the spectrum at the beginning and termination of the blow.

This was readily solved when the numerous lines of the spectrum were attributed to carbon, but in proving them to be caused principally by manganese their disappearance is not so readily accounted for.

One theory to account for it is, that the luminous power of the flame is too small at the beginning and end of the process to produce a spectrum. In regard to this it may readily be shown that the brilliancy of the spectra of incandescent metallic vapors does not depend upon the illuminating power of a flame, but upon the heat of the flame into which they are introduced. For instance, the spectra are more distinct in the non-luminous flame of a Bunsen lamp than in the ordinary luminous gas-flame. If we take the theory as referring to the feebleness of light given off by those substances in the flame, which produce the spectrum, it will resolve itself into the one of change of temperature, notwithstanding the fact that the illuminating power of flames of the same temperature varies with the composition of the gas, because there is evidently enough sodium in the flame to give its characteristic line: hence, whatever might be the illuminating power of the flame, if the heat is sufficiently intense the sodium line *will* show itself.

Dr. Wedding adopts the theory that the absence of the spectrum at the beginning and termination of the blow is because the abso-

lute quantity of the bodies volatilized producing the spectrum is at these times too small. His reasons for holding this view are as follows: "A trace of sodium will give its characteristic line, but, according to Simmler, a much larger quantity of manganese is needed to obtain a recognizable reaction than that which can be detected by the well-known blow-pipe reaction with carbonate of soda. Consequently, spectrum analysis does not depend alone upon the *presence* of a body, but also upon the presence of a certain quantity. And although manganese is always left in the iron, it may not be left in sufficient quantity at the termination of the blow to produce the spectrum, and for this reason the lines disappear."

To this theory there are some strong objections. 1st. If we take manganese in sufficient quantity, and hold it in a flame, the spectrum will increase in brightness until a uniform temperature is attained; but when the amount of manganese vaporized begins to diminish, its spectrum will gradually decrease in brightness until it disappears. Now, if the disappearance of the manganese lines in the Bessemer spectrum is owing to the diminution of the quantity of manganese, we should infer that these lines would gradually grow more indistinct, and then fade away; but, on the contrary, the manganese spectrum increases in brilliancy from its first appearance, and is more intense just before being swept away than at any other time. The analysis of the smoke, which appears when the flame ceases, proves that a considerable quantity is still volatilized, and it is notable that in manganiferous iron this quantity increases towards the close of the blow. 2d. It would be more difficult to account by this theory for the non-appearance of the sodium line at the beginning of the blow, as sodium then in all probability exists in the issuing gas in sufficient quantity to produce its spectrum at a high temperature, as it is only by special precaution that we can keep it out from any flame. 3d. A still greater difficulty would arise in applying this theory to the spectra of sodium and lithium at the close of the blow. As has before been stated these lines sometimes disappear at the moment of complete decarbonization, and sometimes remain. In the former case, to say that our friend sodium had given out would be doing great injustice to that element, as it has never given us reason for bringing so grave a charge against it. Dr. Wedding, in attempting to demonstrate that the non-appearance of the manganese lines is owing to the lack of sufficient quantity volatilized to produce its spectrum, makes the following statement:—

From analyses made by Brunner we find that the manganese contained in the iron falls from 3.460 per cent in the raw material to 1.645, 0.429, and finally to 0.113 per cent in the decarbonized product; and that the protoxide of manganese in the slag first increases from 37.00 per cent to 37.90 per cent, and then sinks to 32.23 per cent, and, furthermore, that a certain quantity of manganese is to be found in the smoke. How much manganese is really lost by volatilization cannot be determined, since *data* are wanting as to the absolute quantity of slag and iron; consequently we cannot determine how much manganese has been lost by means of the eruptions.

But since the manganese contained in the pig-iron decreases constantly, and that contained in the slag after the termination of the boiling period also decreases, a considerable volatilization of this body is probable just at the time when the spectrum is best developed. Comparing with this the experiments that can be made in the laboratory we arrive at the hypothesis, that the oxidized manganese which has entered into the slag is not volatilized, but is retained by the slag; it can, therefore, get into the flame only in the shape of solid or fluid combinations.

In the above statements the results of the analysis prove that some of the manganese in the slag is volatilized. We cannot consider the manganese spectrum during the entire process as due wholly to the volatilization of the manganese directly from the iron, for while the amount eliminated from the iron grows continually less, the manganese spectrum grows brighter. Owing to the intimate mixture by the blast of the iron and slag, the manganese oxide contained in the latter is brought in contact with the melted iron and vaporized. The mixing of the slag and iron would cease at the termination of the process, and this would account for the sudden diminution of smoke.

If there were a sufficient carbonic oxide flame to render the escaping gases glowing, it is evident they would not issue from the converter as dark smoke, but as incandescent vapor, having its characteristic spectrum. The lack of sufficient flame may, therefore, account for the disappearance of the manganese spectrum. The Bessemer flame presents other problems, and opens an intensely interesting field for scientific investigation; and, by the use of more delicate instruments than have yet been employed for this purpose, discoveries may be made which will throw new light upon the subject of spectrum analysis.

3. On American Iron Sands. By T. S. Hunt, of Montreal, Canada.

(Abstract.)

The presence of black iron sands upon many sea beaches has long been noticed both in Europe and America. Their origin is to be found in the crystalline rocks, from the disintegration of which these sands have been derived. The action of the waves, by virtue of the greater specific gravity of these sands, effects a process of concentration, so that considerable layers of nearly pure black sand are often found on shores exposed to wind and tide. These black sands vary in composition according to the localities, but, as found on the coast of New England and the Gulf of St. Lawrence, consist of magnetic oxide of iron, with a large admixture of titaniferous iron ore, and more or less garnet, the purest specimens holding from thirty to fifty per cent of magnetic grains. Such sands have long been employed as sources of iron in India, where they are directly converted in small furnaces into malleable iron. Early in the last century the considerable quantities of these sands found on our Atlantic coast attracted the attention of the colonists and of scientific men in England, and the Virginia sand-iron, as it was called, was the subject of many experiments. The first successful attempts at working it were, however, made in Killingworth, Conn., where the Rev. Jabez Elliot, grandson of the celebrated John Elliot, the apostle of the Indians, early turned his attention to the abundant black sands of the coast, and succeeded in treating them in a forge fire similar to the German forge or modern American bloomary fire. It appears from his account, laid before the Royal Society of London in 1761, that he was then making iron blooms of fifty pounds weight from this ore, and that his son had already established a steel factory in Killingworth, when an act of the British Parliament forbade the manufacture of steel in the colonies. The London Society of Arts, in 1761, awarded a medal to Mr. Elliot for his discovery. The working, however, was abandoned, and for a century no attempts were made in America to use these sands. Some four years since the large quantities of them in the lower St. Lawrence attracted attention, and successful trials were made for their reduction in the bloomary fires of Northern New York; after which an establishment for working them was erected at Moisie in the Gulf of St. Lawrence, where, under the direction of skilled workmen from Lake

Champlain, the treatment of these iron sands has been successfully carried on. These sand ores are remarkably free from both sulphur and phosphorus, and hence yield an iron of great purity and toughness. The working is effected in forges like those used on Lake Champlain, and presents no difficulties.

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4. The Parallel Striæ or Indented Cross-lines on Rock Crystal. By Lewis Feuchtwanger, of New York, N. Y.

It is not my intention to give here a monograph of quartz or rock-crystal; the mineralogical works have mostly done so. But the peculiar phenomena, which I had often had occasion to observe, while examining specimens of quartz in my cabinet from the various localities, and particularly those from the hot springs in the Ozark Mountains, attracted my particular attention, and I have thought that a part brought with me for the inspection of the members of the Association may be interesting, and may lead to further investigations. I allude principally to the parallel striæ, which are deep indented lines drawn across the prismatic faces, as if with a diamond or other harder mineral than quartz, showing, however, only on alternate sides; *i. e.*, one side having the lines, and the rest possessing a smooth surface. The form of all these crystals is the same as those from all other localities, mostly six-sided prisms with pyramidal terminations, and in many other modifications, some widely differing from those from other localities. Such, for example, are the flattened crystals, in which the original and primitive obtuse rhombohedron is totally converted into a flat, obtuse pyramid terminated on both ends, and the crystals crossing each other and displaying the greatest diversity of forms, such as no other mineral species does, but extremely beautiful in appearance. Among the specimens herewith presented is a fine hexahedral loose crystal from Brazil, called the Brazilian pebble, mostly used in the arts for spectacles and lenses. It is perfectly limpid, showing on the surface some interruption during the process of crystallization. The large black six-sided prism from St. Gothard displays no disturbance; nor does the North Carolina group show any lines. The one from New Hampshire, inclosing needles of rutile, displays

some lines wide apart; that from Placerville, Cal., which is found as a large boulder among the auriferous sandstone, has no external lines, but appears to be different on the inside, although of a white color. The specimen from Dauphiné, in France, presents a very fine group of regular prismatic crystals, which abound there in drusy cavities in the mica-slate. The quartz in the form of pseudo-morphous sandstone from Fontainebleau, near Paris, the many fine pseudo-morphic calcites from Saxony, the fluor pseudo-morphs from Devonshire, and the fine rock-crystals from Cornwall, England, which are dug out in the slate quarries, all show smooth surfaces, without those peculiar cross-lines displayed in the specimens from the Hot Springs, and those which are found in Collyer Creek, at the Walnut and North Forks, which are tributaries of the Ouachita River, in Montgomery County, Ark., about thirty miles distant from the famous springs. It may, however, be seen that the opaque quartz crystals, which are studded with many octahedral crystals of arkansite, and are found mostly on the surface, in a place called Magnet Cove, do not show any marked lines, but other incongruities.

Dr. Beck, in part third of the "Natural History of New York," says that that State is particularly rich in quartz, including the transparent, highly crystallized varieties, the rock-crystal, and that the specimens present beautiful iridescence, both superficially and internally; that they also enclose foreign substances, such as anthracite, bitumen, titanic oxide of iron, etc.; moreover, that probably no part of the world affords more beautiful and more interesting crystalline forms than Herkimer County; that he had examined many hundred modifications of the quartz crystals in the several counties, and that, on account of the large number of localities, he could describe only the most important, which are celebrated for their mineralogical specimens. Certain it is that no mineral species affords such a vast variety of forms as does the quartz family, and may be classed, in this respect, next to the calcspar, which yielded to Breithaupt eight hundred modifications.

The chemical constituents of quartz are very simple, but its physical properties are very complicated; and by looking only at these isolated quartz crystals of the size of a pin's head, terminated at both ends, and as perfect in form and color as the largest, I cannot help admiring the wonderful mysteries of a Supreme Power, which has laid loose in the ground of Middleville the young sprouts of crystals, to grow up to the different gigantic

sizes, such as we find in Ulster, Lewis, and Herkimer Counties, of the State of New York. In fact, although every county is noted for quartz crystals, the forms of many localities differ from each other; for I can easily distinguish one from another by their peculiar terminations and modifications, especially those from Herkimer County, which appear to possess some post-natal crystals; for you will perceive in a majority of them cavities having the outline of a pentagonal dodecahedron, which, in some instances, are filled up again by smaller or larger regular prismatic crystals, and in some the cavities are left unfilled. It appears to me that this characteristic feature makes the Herkimer County quartz crystals the most interesting in the world; and independently of that, let me remark, that although the Herkimer County crystals are in general very clear and beautiful, possessing much refractory power, almost equalling the diamond, still they contain many foreign substances, such as anthracite, air bubbles, or drops of water, and appear to have undergone much disturbance during their crystallization.

In returning to the main object of this paper, it remains to me a matter of serious reflection how the sharp lines have been produced in those Arkansas crystals, and to which of the great agencies in nature we shall ascribe this wonderful phenomenon. Has the post-natal, second crystallization of liquid quartz produced these regular marks, and how often has it taken place before growing to its present form, and at what stage of crystallization have these beautiful, flat-faced crystals been metamorphosed from their regular prismatic forms, with pyramidal terminations?

The philosophers of the eighteenth century, such as Boyle, Geoffrey, and Tournefort, entertained many crude theories of the origin and formation of stones, mostly, however, following up the original ideas of Pliny and Theophrastus, which all tended to prove that Neptunism was the sole cause, and that stones grew like plants, and still continue to grow.

Boyle maintains, with many plausible reasons, good enough for those early days, — for Boerhave, in his edition of 1751, devotes much space in supporting Boyle's theory, — that every thing in nature was originally in a fluid condition: that the stones prove it, by the following reasons: first, their transparency; second, their geometrical forms, which bear analogy to many mineral salts, like alum, nitre, vitriol, etc., which, when left to crystallization, produce stones; third, on account of their texture. He says that

silver or salts coagulate into masses of a thin, flaky contexture, which he found in divers gems, even with the naked eye, and appearing to him full of parallel commissures, made by the contiguous wedges of little, thin plates of stone, lying one over another, like the leaves of a book a little open, and that the microscope discovers a parallel structure in the most compact of all, the diamond, whence proceeds what they call the grain of those stones, and the difficulty, nay, impossibility, of clearing them against this grain without breaking. Fourth, the color of stones being derived from some coloring matter which could not be so well imparted to them unless in a state of fluidity, — accordingly, many gems have been deprived of their color by continued heating; fifth, the many heterogeneous substances being frequently found enclosed in solid gems.

Geoffrey ascribes crystallization to two different juices, — the stony, or crystalline, and the vegetable juices, — which may be separated by an all-pervading fluid or earth, creating thereby the crystals and forms of stones and plants on their evaporization.

Tournefort deduces stones *ab ovo.* Nature, according to him, observes one general law in the production of plants, stones, and metals, all of which he supposes to arise from their several seeds, and to grow analogously. He found, however, that some stones grow like plants. He also advances many curious theories to account for the existence of round pebbles. The similarity of pseudo-morphism with post-natal growth might throw light on this question, if it were not for this difference, that the pseudomorphs assume the forms of other minerals, intruding upon their natural forms when some local alterations in the structure of the original mineral substance take place, as may be seen in some of my specimens, the crystalline forms of calcareous spar, fluor-spar, and baryta, siderite, etc., filling spaces and cavities of quartz crystals; post-natalism, on the other hand, refers to cavities left vacant by former crystals, and filled with the same substance either fully or partially, but invariably by the same substance, with perhaps some modification of the crystalline forms. While the quartz was still fluid, and undergoing either the paragenetic or post-natal states, many foreign minerals have made their appearance. Thus we daily see topaz, corundum, chrysoberyl, garnet, hornblende, and pyroxene, asbestos, zeolites, and calcites, rutile, hematite, goethite, magnetite, gold, silver, anthracite, etc., all penetrating the quartz rock when still in a fluid state.

It is evident, therefore, that quartz is more suitable to undergo such metamorphoses than any other mineral substance, owing to its wonderful physical and chemical characteristics. It belongs to the great family of sand, or sandstone rock. Silica, or oxide of silicum, constitutes one-fourth of the earth's crust; one-half of granite and gneiss rocks, and two-thirds of the mica-schist roofing-slate; in many localities the rocks consist entirely of pure silica; the bottom of the ocean and lakes and rivers is formed of granules of quartz rock. Quartz is represented in all geologic ages and periods, from the azoic to the tertiary, and even to the present era, of which the geysers and hot-springs give ample proof. The peculiar characteristics of quartz are its great hardness, insolubility, and resistance to chemical and atmospheric agents, its infusibility, but capability of being acted upon by heat in the presence of the least trace of an alkali, to be readily dissolved, and to enter into new combinations, or fill with quartz fissures and cavities among the rocks. Thus veins are formed which either harden or are changed into new substances, and present the strange phenomena which led me to the present inquiry.

Whether the remarks or hints here thrown out, as a partial explanation of the wonderful forms of rock-crystal, have fully satisfied my audience is doubtful. These phenomena, as well as many others daily taking place around us, have never yet been satisfactorily explained.

VII. MOLECULAR PHYSICS.

1. Elasticity as a Feature in Physics. By S. J. Wallace, of Keokuk, Iowa.

Elasticity is a principal element in Potential Physics, and a part in nearly every practical problem. It modifies every action of force; and every important result requires of it special conditions.

It is a well-known fact. Many of its particular laws are distinct but its general principles are still obscure; and the theory calls for a review of its ground, both as to what is fact, and what hypothetic.

Its Nature.

The nature of elasticity, as it is known to us, is: — The condition of matter or substantial agency, which enables it to receive and give off force as simple motion, or its virtual.

The apparent forms of elasticity are not absolute, but depend on circumstances. It has three primary kinds of action: —

1st. That of Pure Solids, which act as entire bodies, without internal change.

2d. That of Fluent Springs, which move their parts on each other, and forcibly return.

3d. That of Compress Springs, which move their parts to or from each other, with return action.

These actions are all present, to various extents, in all apparent cases.

Usual Forms.

The usual forms in which elasticity is shown, are: —

1st. Hard Bodies, or any bodies with sudden action, which act like pure solids; and even fluids, gases, etc., if extremely intense.

2d. Hard Bodies of most kinds, with graduated action, which act with small internal change under force, and forcibly react.

3d. Bodies of various consistencies, which move their parts on each other under force, and have more or less tension for forcible recovery.

4th. Liquids, of various consistency, which contract or expand their bulk under pressure, with tension to react to size only.

5th. Gases, which contract or expand bulk under varied pressures, with tension to forcibly expand freely to any shape.

6th. Vacuity, as apparent void, which rapidly conveys some forces, without a change of their form, direction, or quantity.

The laws, features, and facts of each of these form a branch of science.

Usual Results.

The principal results of elastic action, as known, are: —

1st. The conveyance of force in virtual direct lines, with no change of kind or amount of force, as in the first and sixth stated forms.

2d. The propagation of force into internal actions in the mass, with tendency to separate into direct, reverse, or diverted force,

of the same or some other form of force, as in the several intermediate stated forms.

The first may be due to the hardness of the ultimate particles; and the second to peculiarities of union among the particles, and to the continuous forces which bear on the mass, to maintain it relatively.

Incidental Forms.

The second stated result has several incidental ways of appearance:—

1st. Bending; flexure between portions of body, direct.

2d. Torsion; twisting between parts of body, rotary.

3d. Extension; drawing out of body, direct.

4th. Extension; drawing in of body, direct.

5th. Expansion; increase of body, evolved.

6th. Compression; decrease of body, involved.

7th. Fluence; change of form, and relation of parts, relative.

8th. Wave Vibration; tremor of vibration running through mass, direct.

9th. Swing Vibration; tremor of parts swinging back and forth.

10th. Mass Motion; passage or revolution of body in space as a whole.

These are merely combinations of the principles of action; and have their several laws of detail, potential formulas, and capacities for use.

Virtual Theory.

We may complete the actual theory with the virtual potency of the known facts, laws, and consistent hypotheses.

It must depend upon the general laws and relations of physical being, and on the internal structures and actions of masses. To reach it we can look to the most simple relations of the particles of matter and actions of the forces. This, perhaps, is to be found in the apparent state of vacuum, or the interstellar space, in a most favorable condition of being and action for definite study of prime relations.

In Vacuity.

There are two forces, gravity and radiance, which pass the interstellar space with forcible fulness and variety. Their passage is by far the most rapid of known actions, and shows no change of

directions, and no loss, or change of kind, of the forces, and other clear facts.

These give important elements of the problem. They require of vacuity the highest possible condition of substance for conveying force with rapidity and purity: the free motion of a body in space, the most pure transmission of force; and there is no known limit to its possible speed through vacancy. But as the interstellar space contains continuous actions in an infinitude of directions, there must be interminable interferences. This becomes a feature of the problem, and requires a review of the essential and potential terms involved.

Force.

The essential nature of physical force is supposed to be:—The movement or action of substance in space during a time, with definite portions and directions obstructive to each other, and communicable from part to part of substance by contact, and equal exchange of opposing energies in action and reaction, with a series of forms of forces that severally have laws, and exist under ranges of circumstances, and capacity of change between forms in series.

This requires the vacuous medium to consist of substance, and that it shall be in continual motion in all directions among its parts, limitedly.

Substance.

The essential nature of physical substance is supposed to be:—The simple obstructive occupancy of a space during a time, with definite portions having extent and place, and capacity to hold co-proportions of force by rates of action in space and time, qualified by the form and law of the force, with determinative law-forces, and separable parts acting in diverse unions and forms, and showing diverse kinds, qualities, and relations to each other.

This requires existence of substance in a state of finely separable particles, extremely small, with interspaces or capacity for relative intermotion or action; and different aggregations.

Potential State.

The particles of substance in vacuous space, as well as in gases, etc., are supposed to be "held in a state of elastic equilibrium," by which uniform distribution is caused, and forces interpassed by

repulsive or other impulses. But how could such a state be composed? It must result from the nature and action of the particles themselves. And there are two types of ideas; that either, —

1st. The particles may be expansible and compressible, or have coverings of such a nature, and inter-extend in space according to pressure, or

2d. They may be small, simple, hard, and free to move in space in any direction for conveyance and exchange of force, by contact.

They differ in whether particles are hard bodies in a vacancy, or are compressible with or without vacancy. This raises the question: What are the laws of transmission of force through substance of various consistencies, and with various kinds of action? This remains a physical problem.

Impressions.

From what is known the facts are suspected to be like these: —

1st. Hard solids transmit force faster than compressibles.

2d. Compressibles are liable to either retain, or to divert into other directions or forms of force, a portion of force-actions.

3d. Simple mass-motion in direct lines through unimpeding space is the most swift transmission, with some not yet known term of relation between size and consistence of bodies, the forms of forces, and the resultant velocities.

4th. Exchange of forces by contact is more quick and complete between hard solids than compressibles.

5th. Therefore the interstellar space has its particles, simple hard solids, separated in free space or in unions, in constant action, conveying force in all directions; each body moving in a single direct line till it comes in contact with another, when instant exchange of forces occurs, and the body passes in the direction of the new force; conveying forces in right lines without change; showing tension for expansion, capacity for fluency, for compression of bulk and return, with continual intermixture, and uniform distribution in space.

Further Considerations.

The forms of force, gravity, and radiance, which freely pass the interstellar space, differ in velocity, gravity being, perhaps, many times the most rapid. Radiance is probably wave vibration, and has a range of sub-forms differing in the rapidity of repetition, with different kinds of effects, as heat, light, and actinic rays, but all

having a common speed in space. And it is possible that gravity and other forces may have a like nature in themselves.

No force is confined to a single absolute speed; for its base of origin may have motion to or fro in the line of force, adding to or taking from the absolute rate in space; with a possible range of variation double the highest possible speed of its source. This raises a question of rates of light in astronomy, and corrections; and, also, the question of approximation of character among the forces by their approximations of velocity, but leaves still wider differences.

Inter-relations.

How do velocities of force so different as gravity and radiance come to take place through one medium, while in radiance several forms of force have different wave-lengths, with but one rate of speed in space? Sound resembles radiance very much in this and other respects, having several forms with a single rate of speed, which is near that of air flowing into a vacuum. This analogy and fact may give a question of relation between the power of a medium to convey a vibration, and that to convey initiate force as mass-motion; and, with some other facts, may raise a suspicion that each force may have an appropriate grade or consistency of medium for passage or action, more or less extensive; in which, perhaps, besides sizes of movable parts to suit wave-lengths, small, simple, free parts, as units of action, may give greater rapidity in space than when the amount of each impulse is so large as to extend an action through more complex bodies and masses.

Classes of Force.

Gravity and radiance represent two classes of forces. Light, heat rays, actinic rays, heat, chemical action, and electricity are closely correlated and interchangeable, and act with proportion to the chemical equivalents of matter; while gravity, mass-motion, etc., have also like close relations, and act with proportion to "inertia," or capacity for "mass" force. The two proportions are very different. The two classes have between their parts regular co-rates of energy; but each class has its different rate of capacity for each element and combination of matter, without direct relations between them.

Hypothesis.

We can, to meet such a state, suppose gravity, mass-motion, etc., to represent the action of unit particles, perhaps alike in all matter; and radiance, chemical action, etc., to represent the action of unit atoms formed by unions of the particles, and forming the several elements, each unit of action conveying a proportion of force regular for its class; and that the relative differences for each element may arise from the relative number of unit particles that go to form an atom unit of the element, while the relative differences of speed of the classes of forces may arise from the relative ease of quickly communicating full force of impulse through the whole body of the unit, supposing the atoms to be permanent unions of particles, in which the particles have some interaction among themselves as units.

Other sizes of mass and consistencies may also form units of action for other impulses of force, forming other kinds or classes of forces, with correspondingly larger and slower wave vibrations.

Question.

But what cause holds the particles in particular unions as atoms? This is ground for a variety of speculations. We could imagine they were created together of such interlocked shapes that they must remain; or that their shapes were such that, in the ever beating of impulses from all sides, they would find a condition of relative rest together; and other suppositions. But, in fact, this resolves itself into the whole broad question of all apparent attractions of matter in all sized masses. It is evident it must result from some ever-acting force; and if the forces are repulsive waves, how do they show an attractive action? That they do so has become a familiar idea, which has a certain plausibility in hypothesis.

Supposition.

The wave forces of gravity, passing through the tenuous substance of space, are supposed to strike masses of more dense matter, and to cause mass-motion when the masses are not supported on all sides alike. The impulses are supposed to come from all directions continuously; but are supposed to be weaker on the sides toward other dense matter, because the dense matter is supposed, according to its amount, to take up or stop the repulsive

power of the force in passing it; thus making an apparent attraction between masses of matter as the result of constant pressures without inter-opposition.

Difficulty.

But how does a dense mass stop the force of gravity from passing it toward all sides? It cannot move to all sides in mass-motion so as to take up all passing forces at once. And this is requisite to meet the case; for gravity acts on all sides of all matter, without regard to its motion.

This fact destroys the supposition, unless some other term is found to interpose; for force must continue to exist, and to act.

Suggestion.

Then what becomes of the intercepted force? The solution must rise from some law of force action. The different forces find different mediums which vary in suitability for action; and when a force meets an unsuited medium it may either be,—

1st. Deflected from its line of direction, in various ways, as in light, etc., or

2d. Changed into some other form of force, as motion into heat, etc.

Now, if the impulse of gravity force is changed into some other form of force, when entering dense matter, then it is possible for it to proceed in its course in the form of another force not so readily convertible into mass motion, and give the required term.

Conclusion.

If gravity and its congeners,—adhesion, cohesion, mass-motion, and perhaps others,—as principals, and the other forces as secondaries, all interchangeable, with different degrees of facility, hold masses of matter together, or in particular states, by constant action, as reviewed in these statements and suppositions; then we have a basis for the theory of elastic action, but requiring yet the laws to be developed and discovered.

2. ON THE ASSUMPTION THAT MATTER IS IMPENETRABLE. By H. F. WALLING, of Easton, Penn.

IN treatises upon physical science, the assumption is usually made as a fundamental principle or axiom, that matter possesses a property called *impenetrability*, by virtue of which every body excludes every other body from simultaneously occupying the same space with itself.

If, however, we examine this assumption in the light of modern molecular science, I think it will not prove to be so axiomatic as it has been considered, and that another cause may be assigned for the powerful resistance which appears to be developed when two bodies are made to encroach upon each other towards a simultaneous occupation of the same space. At the same time it must be admitted that the apparent resistance becomes practically invincible if the encroachment continues, its augmentation being especially rapid in liquids and solids.

In attempting to indicate the true cause of these observed effects, I propose to make no new assumptions, but, on the contrary, to exclude the one already mentioned, as well as the equivalent one embodied in the theory of Boscovich; namely, that any two atoms repel each other at minute distances with a force which becomes infinite as the distance between them becomes infinitely small.

We have only to admit that the law of gravitation applies to atoms, and that no resistance to motion arises even when two or more atoms arrive at the same point, except that occasioned by gravitation itself. It obviously follows that, if two atoms are moving directly towards each other, the momentum imparted by mutual gravitation will carry each of them through and beyond the position of the other. A tendency to subsequent separation is thus produced, corresponding in its intensity to the enormous velocity generated by the continually increasing acceleration maintained during the approach of colliding atoms; and it is this dynamic tendency to separate — constituting, it is true, what we may call a virtual repulsion, and not impenetrability or any real repulsion — that causes apparent resistance to mutual interpenetration. This virtual repulsion, however, though it does not prevent the actual occupation of the same position by two or more atoms during a single instant, limits the continuance of this occupation to an indefinitely small period of time.

The question naturally arises here, Why, if atoms are not impenetrable, should bodies, which are merely aggregations of atoms, not in contact with each other, offer resistance to the passage of other bodies through the positions occupied by themselves? The answer is simple. The only resistances which occur are similar to those which retard the motions of individual atoms. Each individual of the entire aggregate moves with perfect freedom in the path of the resultant force, made up of mutual gravitation, which acts upon it. Indeed, it is only in solid bodies, or those where the motions of the individual atoms are such as to maintain what is called rigidity of form, that an appearance of such a resistance is found.

When two or more gases are brought together, they rapidly diffuse themselves throughout the space which they jointly occupy in such a manner that if any portion of the mixture, however minute, be examined, it will be found to contain each of the component gases in the exact proportions of the entire mixture, a fact which seems to indicate that, sensibly, at least, a complete mutual interpenetration has been effected. The same thing is true of liquids which are mutually soluble. True, if no chemical union occurs, the entire bulk of the mixed gases is equal before and after the mixture; but may we not suppose that this is due, not to impenetrability, but to the production of a virtual repulsion by the dynamic force of the moving atoms in the manner already described?

In discussing the apparent resistance mutually developed when solids impinge, it becomes important to understand how their rigidity of form is maintained. A hypothetical explanation of this has been advanced in papers read by me at previous meetings of this Association. It may be briefly repeated that each physical molecule of a solid body is supposed to be composed of three circular or elliptical rings, made up of simple atoms or chemical molecules, whose distances apart are very small in comparison with the dimensions of the rings or orbits. These three rings revolve about a common centre of gravity in three different planes at right or oblique angles to each other, the inclination of the planes and ellipticity of the orbits being determined by the relative weight of the three rings which revolve in dynamic equilibrium. Six poles are formed by the crossings of the three rings, at which the gravitating force is augmented, and this determines them as mutual points of attachment for adjacent molecules, thereby constituting crystalline or cohesive attraction, adhesion being the result of

attachments of adjacent molecules at points other than the crystalline poles. The rings themselves have a fibrous character due to the close approximation of the atoms, which imparts a certain tensile strength; that is, a necessity for performing work in separating them. An entire crystal is held together in each plane of orbital motion somewhat after the manner of a latticed truss, whence is derived its rigidity of form.

To cause liquefaction an increase of atomic velocity, or of heat, must be effected, producing such a tendency to eccentricity that the extremities of one of the conjugate diameters which unite opposite crystalline poles in each orbital ring are detached from those adjacent, and the rigidity disappears. If the atomic velocity be still further increased, the orbits become unclosed and hyperbolic, causing the liquid to become a liquid or gas.

Returning now to solids: when two of them, with their networks of interlinked orbits, are made to impinge, accelerations and retardations of atomic velocity are produced in such directions in all the orbits that each impinging body is moved *en masse* away from the other; or if the contact is maintained by pressure, a counteracting force is developed, producing increased velocities, and consequent tendencies to expansion in the ring-orbits, in other words a counter-pressure, which is transmitted through each body, from molecule to molecule, and which is in effect a virtual repulsion between the two bodies.

Admitting a dynamic hypothesis of this kind to be tenable, it follows that the gravitations of atoms, with the momenta produced thereby, are adequate to produce the apparent resistances to encroachment between bodies which are brought into collision, both as to change of form and to reduction of bulk. Hence, if we adopt the first philosophical rule of Newton to "admit no more causes of things than such as are both true and sufficient to explain their appearances," we must discard the notion of impenetrability as one of those supposed causes which have become unnecessary to explain appearances.

3. Remarkable Case of Freezing Fresh Water in Pipes Submerged in Salt Water. By W. W. Wheildon, of Boston, Mass.

In the summer of 1868, the Mystic Water Board, having charge of the Charlestown Water Works, determined to lay an eight-inch pipe from their service main, near the westerly end of Malden Bridge, in Charlestown, across Mystic River, for the supply of the City Institution, and several private parties on that side of the river. The source of supply for these Works is Mystic Lake, situated in the towns of Medford and Winchester, about five miles from the City Hall in Charlestown. The water is conveyed in a viaduct of brick masonry from the upper part of the lake, about one and a half miles, crossing Mystic River, its outlet, where the stream is very small, to the pumping-house at the foot of Walnut Hill, in the southerly part of Medford. Here it is forced by steam pumps through a thirty-inch pipe, 3277 feet in length, to the height of 147 feet above tide-water level, into the reservoir near Tufts College. From the reservoir it is conveyed to the city, nearly three miles, through a twenty-four-inch iron pipe. At the point above mentioned, near the Malden Bridge, an eight-inch pipe was inserted into the main, and laid underground to the shore of the river; there passing down the abutment wall to the bed of the stream. Following the line of the bridge on its upper side, it was laid in the soft mud, gradually descending towards the channel, passing through which, on the bottom, it was continued on the flats to the opposite shore, where it passed through the abutment, and was continued along the highway. At the abutments, and over a portion of the flats at low tide, the pipe was exposed to the weather; and, to prevent freezing, orders were given by the Board to allow the water to run from some of the service-pipes, day and night, during the cold weather.

The whole length of the eight-inch pipe from the main was 3,854 feet; 805 feet only being in the river from shore to shore. Of this 805 feet, about 300 feet were covered with the salt water at all times of tide, a portion of it being fourteen feet below the surface at low tide. The pipe used was what is known as "Ward's spherical joint" pipe, which adjusts itself to the irregularities of the river-bed. For some time the arrangement worked satisfactorily, and the benefit of abundance of pure water at the City Institution was fully appreciated.

On the night of the 12th of December, however, after a very

cold term (the mercury falling to ten or fifteen degrees below zero), the free running of the water from the service-pipes was nearly stopped, under the belief that the weather had so moderated that there was no danger of freezing. The next day no water could be obtained from the service-pipes, in a stable near the bridge, or at any other point. It soon became probable that the water was frozen in the pipe, and upon examination this was found to be the case: the pipe was filled with ice for the entire distance across the river, although the largest portion of it was from one to fourteen feet under water at low tide. By means of a diver the pipe was bored in mid-channel, as it had been at other points, and everywhere it was found to be filled with ice, showing that the immersion in salt water had not protected it from frost when the water in the pipe was wholly or partially at rest.

The fresh water when it left the reservoir was, no doubt, at a low temperature, which would not be much raised in flowing rapidly a distance of two miles in the main pipe, although underground, — so that it must have been near the freezing point of fresh water, or 32° Fahr., when it entered the eight-inch pipe. The water in the channel of the river, after the tide had run out, flowing over the flats and shallow bed above the bridge, was, no doubt, reduced below 32° (freezing only at 29°), especially as it was in constant agitation. Therefore the fresh water in the pipe in the channel, upon being stopped, would almost immediately be frozen, as it was encompassed by water below its freezing point of 32°, just as it would if surrounded by air below its freezing point. The Mystic River, above Malden Bridge, where the flats are of considerable extent on both shores, forming a large open bay at high water, is said to be remarkable for what is called "anchor-ice," forming on the bottom of the river.

A few years ago the water pipe of the Cochituate Water Works, passing across the creek between Chelsea and East Boston, was found to be frozen in the same way as the above; and in this case the pipe was not exposed to the weather, but was submerged at all times. A water pipe from the Mystic Works, at one of the wharves in Charlestown, for the supply of fresh water to steam vessels, is kept from freezing by allowing it to run to waste in cold weather, and no difficulty has been experienced in its use. It appears to be certain that fresh water will freeze, in pipes submerged in salt water, when the temperature of the latter is below 32°, unless kept running, although ice will not form in the salt water excepting at the temperature of 29°.

B. NATURAL HISTORY.

I. GEOLOGY AND PALÆONTOLOGY.

1. The Laurentian Apatites of Canada. By Gordon Broome, of Montreal, Canada.

The object of this notice is to direct attention to several points of interest connected with the Apatite deposits of North Burgess, together with notes resulting from the chemical analysis of specimens collected by the author, during the summer of 1870, whilst visiting the district on behalf of the Geological Survey of Canada.

The aspect presented by the entire region is broken and rugged, crystalline Laurentian rocks being abundantly exposed over a large proportion of the total area, whilst the superficial soils are generally of little depth, though often not deficient in fertility. These irregularities of surface do not, however, attain to primary physical importance; but the whole country is thickly sprinkled with barren knolls of Laurentian gneisses and granitic rocks, whilst the lowlands are frequently either occupied by lakes, of which there are a great number, or by heavily timbered swamps or morasses. Occasionally, also, table-lands of minor importance occur; being formed by a somewhat thin capping of coarse-grained sandstones or conglomerates of the Potsdam Group (Zone primordiale of M. Barraude), horizontally and unconformably overlying the upturned and denuded Laurentian rocks.

The district derives its chief importance from the occurrence in it of abundant supplies of the phosphate of lime, Apatite, a mineral of great and increasing economic importance, as well as of considerable scientific interest.

These deposits were partially described in the "Geology of Canada, 1863," as well as in subsequent Reports of the Geological Survey, so that it is proposed only to notice those localities, which may fairly be taken as types of the rest, and to offer a few suggestions as to the probable origin of the mineral, referring those who may desire a more detailed acquaintance with these

subjects to a Report on the Economic Geology of a part of Lanark County, which the author is now preparing for the Geological Survey.

Perhaps the best and most typical examples of the usual mode of occurrence of Apatite in this district are afforded by the numerous exposures upon the north shore of Rideau Lake (lots four to ten in Concession V. of N. Burgess), whence much mineral has been extracted by the Rideau Mining Company, and especially by the veins upon the fourth lot, which are very numerous, have their walls exceedingly well defined, and their courses exactly parallel, viz., north northwest and south southeast (magnetic). They pass down vertically through a roughly stratified Laurentian gneiss, which dips eastward at a high angle, and possesses great hardness, together with a singularly homogeneous and fine-grained texture. The contents of these veins are almost always finely crystallized, consisting of a beautiful rose-pink calcite, enclosing numerous crystals of Apatite, some of which are of gigantic dimensions. Veins, or broad bands of dark magnesian mica (belonging to the species Phlogopite), commonly form part of the main lode, being often characteristic of the walls, and occasionally irregularly intersecting the entire deposit.

The following section, measuring the veins at right angles to their strike, taken on the banks of the Rideau, will show that, in a space of about 76.5 yards, no less than seventeen parallel veins were discovered, having an average breadth of one foot.

None of these veins exceed the "Crystal Lode," belonging to the second series of the above section, either in dimensions, or in the beauty with which their constituents are grouped together. It has an average width of fifteen feet, and is mainly composed of pink calcite, containing very many crystals of Apatite, varying in size from those weighing two or three hundred pounds to others scarcely discernible without the aid of a lens.

Section of Apatite Veins forming a First Series upon the North Shore of Lake Rideau.

No.	Breadth.	Character.
	ft. in.	
1.	1—6.	Tolerably pure Apatite with large plates of mica.
	4—6.	gneiss—more granitoid than usual with this rock.
2.	2—0.	same as No. 1.
	16—0.	gneiss.
3.	0—9.5	Apatite—much calcite.
	11—0.	gneiss.
4.	0—3.	same as No. 3.
	18—0.	gneiss.
5.	1—6.	same as Nos. 3. and 4.
	1—0.	gneiss.
6.	1—6.	Apatite.
	15—0.	gneiss.
7.	0—3.	Apatite.
	5—0.	gneiss.
8.	0—3.	Apatite.
	27—0.	gneiss.
9.	1—1.	Apatite.
	30—0.	gneiss.
10.	0—6.	Apatite with pyroxene.
	18—0.	gneiss.
11.	0—9.	Banded Apatite.
	9—0.	gneiss.
12.	2—0.	large mica plates.
	1—6.	gneissose rock.
	0—1.5	Apatite.
	10—6.	gneiss.
13.	0—3.	Apatite.
	18—0.	gneiss.
14.	0—3.	Apatite.
	5—3.	gneiss.
15.	1—4.	Apatite.
	9—0.	gneiss.
16.	2—0.	Apatite.
	24—0.	gneiss.
17.	0—6.	Brecciated vein with Apatite.

Total Breadth, 76 yds. 1 ft. 7 in.

Section of Series II.

No.	Breadth.	Character.
	ft. in.	
1.	0—6.	Confused vein of mica with Apatite.
	15—0.	gneiss.
2.	3—9.	Banded Vein.
	24—0.	gneiss.
3.	15—0.	the "Crystal Vein."

SECTION OF VEIN 2. SERIES II., SHOWING THE BANDED, OR "RIBBON" STRUCTURE.

	ft. in.
Mica in large plates with Apatite.	0 — 9.
Clear Apatite.	1 — 6.
Micaceous gneiss (?)	1 — 6.

NOTE. — A space of about 440 yards intervenes between the veins of Series I. and those composing Series II.

The main lode is intersected at various angles by bands of dark mica (Phlogopite), occurring in fine hexagonal plates, and often imbedded in a pyroxenic base, whilst the walls are marked by similar ribs of from four to six inches in thickness. In the earthy debris scattered thickly over the outcrop of the vein are found numerous Apatite crystals with brown weathered surfaces, and both ends of the prism roughly terminated; whilst the vogues or cavernous hollows, formed throughout the vein by solution of portions of the calcite, abound in similar fragmentary crystals.

Not unfrequently other minerals may be observed within the Apatite crystals, among which mica and calc-spar are the most frequent. The mica itself often contains crystals of the spar, or minute prisms of Apatite; whilst one very instructive example was obtained, that showed a large thick plate of mica, which had been apparently torn asunder, in the direction of its basal cleavage, and at the same time curved and twisted, the clefts being occupied by veinlets of clear sea-green fluophosphate of lime.

On the whole it may be said that this remarkable vein has yielded to collectors the finest known specimens of Canadian Apatites.

It will not be necessary to describe here any other of the Apatite veins of this district, all of which have a dip not far removed from the vertical, whilst most of them exhibit a marked tendency to parallelism of strike. Indeed, with regard to the strike of these lodes, it appears that there are two directions, the one, and the most frequent, approximately at right angles to the strike of the

enclosing metamorphic rocks, the other coinciding with their direction, and often giving the deposit the appearance of being a bed, and not, as in reality all these deposits are, a true vein.

Whether these two groups of veins had different ages of formation, and originated in fissures formed by forces acting at distinct epochs, the author has not at present been able to ascertain, owing to the extreme difficulty of tracing veins which have been mined to a very small extent only.

Proceeding to inquire what relation the Apatite veins have to their country rock, we shall be able to arrive at certain facts with regard to the period of their formation, which are important as furnishing a reliable clew to the probable origin of the deposits.

The veins are enclosed within stratified granites or gneisses of the Laurentian formation, and they appear to be most abundant in close proximity to those great bands of crystalline plumbaginous limestones, which may be traced for hundreds of miles over these Laurentian districts; and, whilst they are entirely confined to these metamorphic rocks, and do not occur as veins in the overlying Potsdâm sandstones, nevertheless fragments of Apatite, evidently derived from the denudation of the veins, have been observed in the very base of those sandstones.

The sandstones are, as already stated, horizontally bedded, and entirely unconformable to the Laurentian rocks, which are much faulted; and (on the tenth lot of Concession V. N. Burgess), in some instances, the Apatite veins are themselves faulted, their dislocations coinciding with the faults shown by the Laurentian gneisses, whilst the unconformably overlying sandstones are entirely undisturbed.

The period, therefore, at which these Apatites were formed into veins must be one anterior to that of the Potsdam Group; and it follows that no theory which endeavors to refer the origin of the deposits to an organic source can be longer entertained, since the veins existed before the appearance of life upon the earth, except that of the Eozoon, and perhaps of some other organisms of an exceedingly simple and low type. The veins were consequently produced by inorganic agencies, and most probably in a manner exactly analogous to the formation of true mineral lodes; viz., by deposition from aqueous solution, and usually from solution in heated and alkaline waters.

The finely glazed surfaces of the Apatite crystals, as well as the extreme frequency of rounded edges, especially those of the ter-

minal faces, which are usually obtuse rhombohedra, and the fretted and hollowed appearances presented by many of the crystals, are evidently due to a partial removal of the mineral in a state of aqueous solution, such solution being effected, at least in part, by the action of waters impregnated with carbonic acid.

To obtain direct evidence on this point a large quantity of finely pulverized and pure Apatite was placed in two hundred grammes of distilled water, through which a stream of carbonic acid gas was passed for about twenty-four hours, at a temperature of about 60° Fahr.

The loss of weight amounted to .070 grammes; and it may therefore be concluded that, under the conditions mentioned, Apatite is soluble in 2,857 parts of carbonated water. But it must be borne in mind that, in a mineral vein, two other conditions exist by which the solubility of the mineral would be greatly increased; viz., a high temperature, and a pressure much in excess of that existing at the surface: so that this reaction alone may justly be regarded as amply sufficient to carry Apatite into a vein, and deposit it there in crystals having a banded grouping, and bearing marks of the action of aqueous solution in their production.*

Waters charged with carbonic acid share this power of dissolving the mineral phosphate of lime with solutions of ammoniacal salts, and of the alkaline chlorides and nitrates; and this fact possesses, as Liebig has shown, not only geological interest, but is also of the greatest importance to the agriculturist in the selection and employment of mineral fertilizers. Thus, it was found that in chloride of potassium $\frac{1}{1141}$ parts of Apatite were dissolved by digestion for seven or eight days in the cold; whilst a strong solution of ammonic chloride removed $\frac{1}{1828}$ parts, under like conditions.

When phosphate of lime is exposed to the action of waters holding alkaline carbonates in solution, a reaction is established, resulting in the production of carbonate of lime and a phosphate of the alkali; and it is not unlikely that the rapidity of solution

* Mr. L. Feuchtwanger, in a paper read before the American Association for the Advancement of Science, August, 1870, upon the Striation of Quartz Crystals, alluded to this phenomenon, showing a prism of Apatite with a regular perforation thus produced. The author believes that the very marked regularity of such apertures may often be traced to the occurrence of smaller prisms within the larger crystals, and that these have given rise to the aperture, owing to their being more readily disintegrated and dissolved.

has been often augmented by this change, which at the same time may serve to account for the frequent occurrence of calcite within the crystals of Apatite.

Bischof* enumerates all those rocks of the igneous type in which phosphates have been found, and further remarks that the existence of like compounds in many other non-sedimentary rocks may be indirectly inferred from the character of their vegetation, the chemical composition of their soils, and the nature of the minerals contained in their waters.

Clemm † and Forchhammer ‡ have long since succeeded in demonstrating the presence of phosphate of lime in sea-water; and Dana remarks § that analyses of corals by Mr. B. Silliman, Jr., show that they contain small portions of the phosphate and fluoride of lime, together with some silica, alumina, and sesquioxide of iron, these substances being present in quantities, which he considers amply sufficient to account for the presence of such minerals as Apatite, Fluorite, and Chondrodite in many of the crystalline limestones. From these and other considerations, the author has been led to believe that these veins have been produced by purely inorganic agencies, at a period contemporaneous with the alteration of the Laurentian strata into the metamorphic granites and gneisses by which they are now represented, and prior to that at which the Potsdam sandstones were derived from the waste of the old Laurentian coasts.

A certain zone of the Laurentian sediments, and generally of those contiguous to the limestones, which we may conclude were always of deep-sea origin, became, to some extent, charged with phosphate and fluoride of lime, derived from precipitation from solution; and when the rocks composing this belt were subsequently upheaved, contorted, and metamorphosed, vein fissures were abundantly produced, which were gradually filled by Apatite and its concomitant minerals, deposited from their solutions in such a way as to give rise to their characteristic ribbon structure.

The veins so formed in the North Burgess District have not remained in their original form, but have been subjected to the same disturbing forces by which the rocks themselves were affected; and this is proved by the occurrence of brecciated and confused

* Chem. and Phys. Geol., pp. 23–41, vol. ii., Eng. Ed.

† Journ. fur Prakt. Chem., xxxiv., 185.

‡ Berzel. Jahersb., xxvi., 393.

§ Sill. Amer. Journal (2), ii., 1846.

veins, as well as of those ribs, or subordinate veins, of mica, by which the "Crystal Lode," and other veins, are intersected. In some cases there is evidence to show that this disturbance has been often repeated; and it may be that the subordinate group of veins, whose direction coincides with the strike of the rocks, were produced during this subsequent re-arrangement.

The following is an analysis of a portion of a pure crystal of Apatite, sea-green in color, with the usual prismatic form, and giving specific gravity = 3.209: —

Phosphoric Acid	40.11
Lime	48.01
Calcic Fluoride	7.20
Calcic Chloride	0.65
Calcic Carbonate	3.61
Insoluble	traces
Water	0.66
	100.24

Tribasic Phosphate . . . . . 88.12.

Or, excluding impurities, such as carbonate of lime, we should have: —

Phosphoric Acid	42.16
Lime	50.47
Calcic Fluoride	7.56
	100.19

It may be remarked that the Red Apatites from this district, which are not uncommon, and form the whole of many veins, are deficient in the interest attached to those of Arendal and other localities, being free from phosphate of cerium, and deriving their tinge from the presence of a basic phosphate of iron, evidently formed from the action of the strings of hematite and pyrite which sometimes occur in connection with veins of red Apatite.

This condensed notice of the Laurentian Apatites must for the present suffice; but the author hopes to be able to continue the subject in a future communication, as it appears to afford a rich field for researches in Chemical Geology.

2. The Oil-bearing Limestone of Chicago. By T. Sterry Hunt, of Montreal, Canada.

(Abstract.)

When, in 1861, I first published my views on the origin of the petroleum of the West, I pointed out that the true source of it was to be looked for in certain limestones, long known to be oleiferous. These were the Coniferous, the Niagara, and the Trenton, and, in North-western Canada, strata regarded as of the Lower Helderberg age. I subsequently insisted still farther on the oleiferous character of the Coniferous in South-western Ontario, where it appears to be the source of the petroleum of that region. I have maintained, moreover, that the oil is indigenous to these and similar limestones, and has not been brought into them by any process of distillation or infiltration from other rock formations, such as the pyroschists of the Lower Silurian and Devonian. The reasons for this opinion are as follows: 1st, These pyroschists do not, except in rare calcareous bands, contain any petroleum; and their capacity to yield volatile hydrocarbons by destructive distillation, under the influence of heat, — a property which they possess in common with peat, coal, wood, and most bodies of organic origin, — is all that can be affirmed of them. Moreover, the pyroschists in question nowhere present any evidence of having been exposed to a heat such as would be required for the generation of volatile hydrocarbons, and still hold their hydrocarbonaceous matters in a non-volatile condition. 2d, The conditions in which the oils occur forbid the notion that they have been introduced by a process of distillation. This being naturally a process of ascension, the oils of the Upper Silurian and Devonian limestones of the West should have come from the Lower Silurian (Utica) pyroschists; but these are unaltered, and the sandstones and shales between them and the oil-bearing limestones are destitute of petroleum. More than this, the Trenton limestone, which on Lake Huron and elsewhere has yielded considerable quantities of oil, has no pyroschist or hydrocarbonaceous rock beneath it. Still another reason, which I pointed out many years since, is that the oil in the Coniferous limestone is confined to certain bands, or layers, in which it fills the pores and the cavities of fossil shells and corals; while the surrounding portions, though equally porous, are entirely destitute of petroleum.

The only reasonable conclusion from all these facts would seem to be that the oil has been generated in the portions of rock which now contain it, or, at least, that it has existed there, in some form or other, since the first deposition of the rock. Its source I conceive to have been a peculiar transformation of the organic matters which were enclosed in the forming limestone, resulting in the production of a compound destitute of oxygen, and containing a maximum of hydrogen. The nature of this chemical process I have elsewhere explained in the "American Journal of Science," for March, 1863, and have, moreover, given reasons for supposing that many petroleums have been derived from animal organisms.

The object of the present communication is to call attention to the vast quantities of ready-formed petroleum existing in the pores of the paleozoic limestones. In the vicinity of Chicago, Illinois, there is a mass of limestone, estimated by Mr. Worthen at from thirty-five to forty feet in thickness, which is throughout impregnated with petroleum, and is regarded as belonging to the Niagara formation. I selected from different levels in an open quarry near the city several specimens that were supposed to give an average of the oil-bearing limestone, which is in composition nearly a pure dolomite. Two portions of different lots of the broken-up rock were coarsely powdered and heated with hydrochloric acid in the cold, till the carbonates were dissolved, their weights being respectively one hundred and one hundred and thirty-eight grammes. From the insoluble residues the oil was extracted by ether; and the oil, after evaporation in a water bath till it ceased to lose weight, was equal in the two trials to 1.570 and 1.505 per cent of the weight of the rock. It was reddish-brown in color, somewhat viscid, and had a specific gravity of .935 at 62° Fahr. Taking the density of the rock at 2.600, we have for the mean of the above determinations a volume of oil equal to 4.25 per cent of the rock; so each square mile of it, one foot in thickness, would contain 1.184.832 cubic feet, equal to 222,492 barrels, of forty gallons each. Taking the thickness of the oil-bearing limestone at thirty-five feet, we have thus, in each square mile, more than seven and three quarters millions of barrels of petroleum; while the total produce of the Pennsylvania oil for the last ten years is estimated at only twenty-eight millions, or less than the contents of four square miles of a limestone bed like that of Chicago.

Although it would be possible to retract by proper solvents the oil from rocks like this, it is probable that so long as great natural

springs of petroleum are accessible, such a process will never be resorted to. The conditions under which such springs have been produced would seem, as I long since pointed out, to be the fissuring of the oil-bearing strata, connected with disturbances of the stratification, which have permitted a portion of the petroleum to flow out, and to accumulate in rents or cavities in the overlying rocks, which form natural reservoirs. So long as it is proved that the paleozoic limestones contain such enormous quantities of ready-formed indigenous petroleum as we have seen, it appears unnecessary to resort to the gratuitous hypothesis of its production by destructive distillation from coals and pyroschists.

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3. NOTES ON GRANITE ROCKS. By T. STERRY HUNT, of Montreal, Canada.

(Abstract.)

THE name of granite, at first applied to a more or less granular composite rock, consisting essentially of orthoclase and quartz, with a portion of mica, has acquired a meaning both lithological and geological. Rocks possessing the characters just indicated occur in three very different geognostical relations: 1st, As clearly erupted, unstratified masses, which are intruded among stratified deposits, displacing them, and traversing the strata. 2d, Stratified masses, which, by a more or less distinct lamination or parallel arrangement of the constituent elements, show a passage into what is often called granitic gneiss. Such masses present alternations of beds, varying somewhat in texture and in composition; and become in many cases interstratified with micaceous and quartzose strata, in such a manner as to show that they are all members of one contemporaneous stratified system. Such granitic rocks abound in the earlier geological series, for chemical reasons which I have elsewhere pointed out; and hence granite has long been regarded as the primitive, or fundamental rock. From this notion, associated with the fact of the eruptive, unstratified character of the granite rocks of the first class, has arisen the popular idea of a base of non-stratified granite, of igneous origin, which preceded all stratified formations. Such a base is, however, un-

known to the geologist; and the widely spread granitic rocks which have given origin to this hypothesis are, for the most part, not eruptive, but stratified, belonging to the second class, or granitic gneisses. Such rocks may be designated indigenous granites, to distinguish them from those of the first class, which, being foreign to the strata in which they occur, I have called exotic granites. 3d, There is a third class of granitic aggregates, differing in their geognostical relations from both of the preceding, which I have designated as endogenous, to call attention to the fact that they have been formed by a growth within the fissures, or cavities, which they now occupy. They are true veinstones, of aqueous origin, analogous in their mode of formation to those of quartz and calcite, which often form the gangue of metallic ores. Such veins in stratified rocks, more or less calcareous and magnesian, may contain, besides orthoclase and quartz, calcite, amphibole, and magnesian micas; while, in rocks destitute of lime and magnesia, minerals containing these elements are absent from the veinstones, which assume the composition of granites.

The principal object of this paper is to call attention to these endogenous, or veinstone granites, which constitute the pegmatites of some authors, and play a conspicuous part in the geology of some regions, where they are often confounded with eruptive, or exotic granites. Like these, they are seen to be posterior in origin to the crystalline schists which enclose them. They are, however, distinguished from exotic granites by the fact that they are frequently the gangue of rare mineral species, such as beryl, tourmaline, lepidolite, apatite, cassiterite, etc., and by various peculiarities. Thus, while exotic granites are comparatively fine-grained and uniform in texture, the endogenous veins, even if only a few inches in diameter, are often very coarse, holding broad, cleavable masses of orthoclase, and not unfrequently as large ones of hyaline quartz, the two minerals being often arranged in bands parallel with the walls of the vein. This banded structure is sometimes beautifully evident in granitic veins; while at other times the aggregate assumes the character of graphic granite, or resembles very closely an exotic granite. These variations may sometimes be met with in the same vein. The size of these endogenous veins varies from a few lines to fifty feet or more in breadth. Nowhere, perhaps, can they be better studied than in the great belt of crystalline schists which stretches through Eastern New England, from Maine to Connecticut. Thus, for example, in the townships of

Westbrook, Danville, Brunswick, Topsham, Bethel, and Riley, among others in Maine, endogenous granite veins, in great number and of large size, traverse the soft micaceous schists of the region, and, these having been worn down, the harder endogenous granites are very conspicuous. Interstratified with these same schists are great beds of fine-grained granitic gneiss, constituting an indigenous granite. To these belong the so-called granites of Hallowell and Augusta, in Maine; while examples of exotic, or eruptive granite, occur at Biddeford and Saco Pool.

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4. On the Former Existence of Local Glaciers in the White Mountains. By Louis Agassiz, of Cambridge, Mass.

Twenty-three years ago, when I first visited the White Mountains, in the summer of 1847, I noticed unmistakable evidences of the former existence of local glaciers. They were the more clear and impressive to me because I was then fresh from my investigations of the glaciers in Switzerland. And yet, beyond this mere statement of the fact that such glaciers once existed here, I have never published a detailed account of my observations, for this simple reason, — that I could not then find any limit or any definite relation between the northern drift and the phenomena indicative of local White Mountain glaciers; nor have I ever been able since to revisit the region for more careful examination. This year, a prolonged stay among these hills has enabled me to study this difficult problem more closely; and I am now prepared to show that the drift, so called, has the same general characteristics on the northern and southern sides of the White Mountains.

Whatever, therefore, may have been the number of its higher peaks that at any given time during the glacial period rose above the great ice sheet which then covered the country, this mountain range offered no obstacle to the southward movement and progress of the northern ice fields. To the north of the White Mountains, as well as to the south, the northern drift consists of a paste more or less clayey or sandy, containing abraded fragments of a great variety of rocks so impacted into the minutely comminuted materials as to indicate neither stratification, nor

arrangement or sorting, determined by the form, size, or weight of these fragments. Large boulders, and pebbles of all sizes, are found in it throughout its thickness; and these coarser materials have evidently been ground together with the clay and sand, under great pressure beneath heavy masses of ice, — for they bear all the characteristic marks so unmistakable now to those who are familiar with glacial action; scratches, grooves, and furrows, etc. These marks are rectilinear, but they cross each other at various angles, thus showing by the change in their direction that the fragments on which they occur, though held for a time in one and the same position, while these straight lines were engraved upon their surface, nevertheless changed that position more or less frequently. A few flatter fragments, with more angular outlines, show only one kind of scratches, having evidently been held for a longer time in the same position. This drift, however it may vary in its mineralogical compounds in different localities, exhibits everywhere the same characteristic treatment over the whole country, from the shores of the Atlantic to the Rocky Mountains and beyond. In the White Mountain region it has the same mineralogical character north and south of the range, and rests everywhere upon the well-known *roches moutonnées*, — in one word, upon the planed, grooved, polished, and scratched surfaces of the rocks underlying it.

Observation has taught us that materials such as those described above, so combined, exhibiting the same characters on their surfaces, and having the same diversity of composition, and absence of all sorting or regular arrangements, occur now at the bottom of the great glaciers of our own time, and nowhere else, being found between the ice and the rocks over which it moves; the result, in fact, of the grinding action of advancing glaciers. On account of their unvarying position I have called these deposits "ground moraines," because they are always resting upon the rocky floor of the country, between it and the under surface of the ice. Our typical, unaltered, so called northern drift is synonymous with the ground moraines of the present day, differing only in its greater extension. It is, in fact, a ground moraine spreading over the greatest part of the continent. All its characteristics, identical in every detail with those of the deposits underlying the present glaciers, show that it can only have been formed under a moving body of ice, held between it and the underlying mass of rock. The great ice sheet, the glacial period, which has fashioned the

drift, must therefore have been co-extensive with the distribution of the latter. It is very important to distinguish this drift from the moraines formed under other circumstances, and from the so called erratics and perched blocks. Moraines, as commonly understood, — that is, lateral and frontal moraines, consisting of loose materials collected along the sides and at the terminus of a glacier, — always indicate, and, where undisturbed, actually define, the margins of a moving mass of ice; whereas the so-called median moraines, formed along the line of junction of the glaciers, are carried upon the back or upper surface of the ice, and always consist of angular materials, the shape and arrangement of which are determined by their mode of accumulation. Just as among the glaciers of the present day we discriminate between ground moraines, lateral, frontal, and median moraines, so must we also distinguish between the same phenomena in past times. The glacial period had also its ground moraines, its lateral, its frontal, and its median moraines, its erratics and perched boulders. But the huge ground moraine of the earlier ice time stretched continuously, like the ice sheet under which it was formed, over the whole country, from the Arctic to the Southern States, and from the Atlantic to the Rocky Mountains. I do not speak of the Western slope of the Continent because I have not examined it personally. The great angular erratics of that period were scattered irregularly over the country as the few large boulders are scattered on the upper surface of a glacier now. It is the contact of the more limited phenomena of the local glaciers, which succeeded this all-embracing winter (their lateral, frontal, median, and limited ground moraines, and their erratics), with the more wide-spread and general features of the drift, that I have been able to trace in the White Mountains this summer. The limits of this paper will not allow me to do more than record the general facts; but I hope to give them hereafter more in detail, and with fuller illustrations. The most difficult part of the investigation is the tracing of the erratics to their origin: it is far more intricate than the identification of the origin of ordinary drift, or of continuous moraines, because the solution of the problem can only be reached under favorable circumstances where boulders of the same kind of rock can be followed from distance to distance to the ledge *in situ* from which they were detached.

Now, in the neighborhood of the White Mountains, we find, beside the typical, or northern drift, large erratic boulders, as well as

lateral, frontal, and median moraines. A careful examination of these shows, beyond a doubt, that they came from the White Mountains, and not from the northern regions, since they overlie the typical drift, which they have only here and there removed or modified. A short description of the facts will leave no doubt upon this point.

The finest lateral moraines in these regions may be seen along the hill-sides flanking the bed of the south branch of the Ammonoosuc, north of the village of Franconia. The best median moraines are to the east of Picket Hill and Round Hill. The latter moraines were formed by the confluence of the glacier which occupied the depression between the Haystack and Mount Lafayette and that which descended from the northern face of Lafayette itself. These longitudinal moraines are particularly interesting as connecting the erratic boulders on the north side of the Franconia range with that mountain mass, and showing that they are not northern boulders transported southwards, but boulders from a southern range transported northwards. But by far the most significant facts, showing the great extent of the local glaciers of the White Mountain range, as well as the most accessible and easily recognized, even by travellers not very familiar with glacial phenomena, are the terminal moraines to the north of Bethlehem Village, between it and the northern bend of the Ammonoosuc River. The lane starting from Bethlehem Street, following the Cemetery for a short distance, and hence trending northwards, cuts sixteen terminal moraines in a tract of about two miles. Some of these moraines are as distinct as any I know in Switzerland. They show unmistakably by their form that they were produced by the pressure of a glacier moving from south northwards. This is indicated by their abrupt southward slope, facing, that is, toward the Franconia range, while their northern face has a much gentler descent. The steeper slope of a moraine is always that resting against the glacier, while the outer side is comparatively little inclined. The form of these moraines therefore, as well as their position, shows that they have come down from the Franconia Mountains. A few details concerning their location may not be out of place, in order that any visitor interested in the facts may readily find them without a guide. The ground to the north of Bethlehem slopes gently northward, and is not wooded for about half a mile from the street. Following the lane above mentioned, the first moraine reached skirts the edge of the wood, and near the

houses of Mr. Phillips there are four others, more or less distinct, before reaching a little trout brook called "Barrett's Brook." The lane descends more rapidly towards the brook than before; and, where the descent begins to be steep, the eye commands the space between the brook and a higher ground, on which stands a house owned by Henry McCulloch. Over that interval six very fine moraines may be counted, one of which is perhaps the finest specimen of a terminal moraine I have ever seen. Beyond McCulloch's there are five more, not quite so distinct. The ground beyond the termination of the glacier of the Rhone, in Switzerland, is celebrated for its many distinct concentric terminal moraines; but here we have a field over which, within the same area, a larger number of such moraines may be seen, and I believe that a pilgrimage to this spot would convert many a sceptic to the true faith concerning the transportation of erratic boulders, especially if he has seen the glaciers of the Rhone, and can compare the phenomena of the two localities.

The Littleton road from Bethlehem, and the roads to Franconia Notch from both these towns, frequently intersect terminal moraines. Those familiar with the topography of the Franconia range, and its relation to Picket Hill and the slope of Bethlehem, will at once perceive that the glaciers which deposited the front moraine to the north of Bethlehem Village must have filled the Valley of Franconia to and above the level of the saddle of Picket Hill, making it at least fifteen hundred feet thick, if not more,— thicker, in short, than any of the present glaciers of Switzerland. It will be observed, also, that as soon as the northern portion of that glacier had retreated to the wall which encircles the Franconia Valley on the north, the glacier, occupying henceforth a more protected valley within the range, must have made a halt, and accumulated at this point — that is, south and west of the saddle of Picket Hill — a very large terminal moraine. This moraine actually exists to the present day, and is one of the most characteristic features of the distribution of erratics in these regions. From the moment the glacier was reduced to the level of Franconia bottom it must suddenly have vanished entirely from the whole valley, and thus it happens that no other large terminal moraines are seen between that just mentioned and the higher range of Franconia.

Moraines similar to those observed on the northern side of the White Mountains exist also on their southern side, in the vicinity

of Centre Harbor. Lateral moraines may be traced at the foot of Red Hill, a little above Long Pond; also, along Squam Lake. Median moraines are very distinct near Centre Harbor Hotel. Terminal moraines are also numerous near Centre Harbor, and in the neighborhood of Meredith. At the southern end of Red Hill the lateral moraines bend westward, and show their connection with the terminal moraines. These facts, taken in their relation with those enumerated above, show that there were local glaciers on the southern as well as the northern slopes of the White Mountain ranges, moving in opposite directions; those on the northern slope moving northward, and those on the southern slope moving southward. I have seen no evidence thus far of these northern glaciers extending beyond the range of hills which separates the Ammonoosuc River from the Connecticut River Valley west of Lancaster, nor have I traced the southern glaciers beyond Lake Winnepesaukee. Traces of an eastern glacier, moving westward, may be seen near the Twin Mountain House; but I have not examined that region with sufficient care to give minute particulars.

All these moraines and traces of local glaciers overlie the typical, or northern drift, so called, wherever the latter has not been entirely swept away by the local glaciers themselves; thus showing that the great ice sheet is anterior to the local glacier, and not formed by a spreading of smaller pre-existing glaciers. At least, wherever I have recognized traces of circumscribed glaciers in regions where they no longer exist, it has always appeared to me that the minor areas covered by ice were remnants of a waning sheet of greater extent. If the glacial period set in by the enlargement of limited glaciers already formed, and gradually spreading more and more widely, as Lyell and the geologists of his school suppose, the facts which would justify such a view are still to be made known. I have not seen a trace of them anywhere; on the contrary, throughout the ranges of the Alps, in the Black Forest, the Vosges, as well as in the British Islands, in Scotland, Wales, and Ireland, I have everywhere satisfied myself that the more extensive the glaciated areas indicated by polished surfaces and moraines in any given locality, the older they are when compared with glacial phenomena circumscribed within narrow limits.

It therefore follows from the facts enumerated above, as well as from a general consideration of the subject, that the local glaciers of the White Mountains are of a more recent date than the great ice sheet which fashioned the typical drifts. On another occasion I

hope to show that the action of the local glaciers of the White Mountains began to be circumscribed within the areas they have covered, after the typical drift had, in consequence of the melting of the northern ice sheet, been laid bare in the Middle States, in Massachusetts and Connecticut, after even the southern portions of Vermont, New Hampshire, and Maine had been freed, and when the White Mountains, the Adirondacks, and the Katahdin range were the only ice-clad peaks in this part of the continent.

When, in their turn, the glaciers of the White Mountains region began to melt away, the freshets occasioned by the sudden large accumulation of water remodelled many of these moraines, and carried off the minute materials they contained, to deposit them lower down in the shape of river-terraces. I have recently satisfied myself by a careful examination that all the river-terraces of the Connecticut River Valley and its tributaries, as well as those of the Merrimac and its tributaries, are deposits formed by the floods descending from the melting glaciers. What President Hitchcock has described as sea-beaches and ocean-bottoms near the White Mountain and Franconia Notches, as well as in the Connecticut River Valley and along the Merrimac, have all the same origin. The ocean was never in contact with these deposits, which nowhere contain any trace of marine organic remains.

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5. Boulder-trains in Berkshire County, Mass. By John B. Perry, of Cambridge, Mass.

Lines of erratics are occasionally met with in different parts of the country, but they are nowhere better exhibited than in Richmond, Berkshire County, Massachusetts. In that neighborhood there are six or seven nearly parallel trains of angular boulders, two of which are particularly well defined. Attention was called to the marvellous arrangement of these travelled rocks, years ago, by my friend, Dr. Reid, of Pittsfield. They have been likewise referred to, and in part described, by Sir Charles Lyell and the late President Hitchcock.

These boulder-trains originate partly in a nearly meridional range

of hills, consisting of chloritic slate, in Canaan, Columbia County, New York; but more especially in two other parallel ranges of peaks with a like trend, situated near the State-line in Richmond. The latter ranges are also mainly composed of a greenish slate, which contains extensive beds of interstratified limestone. For the most part, the character of the boulders is such that they can be readily traced back to their exact source, — those of the two most prominent lines to isolated peaks of the Canaan hills; those of the other trains to similar heights in the Richmond ranges. Some of these tracks of erratics may be followed south-easterly for four or five miles; others, passing over the Lenox range of hills, can be traced for ten or fifteen; and one of the larger, for some twenty miles. Their direction, in the first portion of their course, is south about 55° east. Somewhat further on they change their trend, it being for the most part some 35° east of south.

President Hitchcock, presuming that there was a submergence of the region during the glacial period, speaks of these lines of erratics as *osars*. Sir Charles Lyell, also supposing a depression of the country, thinks these boulders were transported by coast ice. Professor Rogers, in order to account for such phenomena, has assumed the occurrence of a vast wave of translation.

There being no evidence, as shown in a previous paper, of any considerable depression of this part of the continent during the ice period, — even if a submergence would afford an adequate explanation, which it does not, especially when we remember the straight course marked by the parallel lines of erratics over high hills, and through the deep valley of Richmond, — the question now arises, How are we to account for these boulder-trains? To this query I reply in the fewest words at my command.

As the vast ice sheet which spread over the country gradually wasted, the elevations from which these boulders were derived would be at last laid bare. The ice no longer passed directly over the tops of the hills; indeed, there is evidence that the mass was parted, moving around the north-eastern and south-western flanks of the several peaks. Of course, under these circumstances, the hillsides would be closely pressed and rubbed, blocks of slate and limestone detached from their places, and borne along by the ice-sheet. This being, in that neighborhood, at the time in question, some six hundred feet in thickness, and continuing slowly to thaw as it advanced, the boulders must be carried forward for a considerable distance, and finally left resting upon the typical drift, as we

now find them. The ice gradually wasting, there would likewise be changes in the direction of the moving mass, determined by the character of the underlying surface of solid rock, thus causing the variation observable in the trend of the boulder-trains, in the latter part of their course.

Such, in brief, is the explanation which I would give of these lines of angular rocks, — an explanation which is applicable to similar phenomena in Huntington, Vt., and in some other parts of New England; an explanation which, taking from these instances the exceptional character which has been given to them, regards them as legitimate concomitants of the last great winter of the ages; an explanation suggested to me by the study of these strange remains in the light derived from the researches of Professor Agassiz, on the existing glaciers of Switzerland; an explanation which, while it is in entire consonance with all the known facts connected with the glaciation of the country, has the great advantage of requiring no resort to an arbitrary theory of submergence.

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6. The Supposed Elevation and Depression of the Continent during the Glacial Period. By John B. Perry, of Cambridge, Mass.

Many geologists suppose that there was an extensive elevation of the northern part of America, at the close of the Tertiary Era. This they think was necessary in order to the existence of the ice period, and of the phenomena peculiar to it. Instead of resorting to a supposition of this kind, which is wholly unauthorized by positive evidence, I prefer to cling to facts, invoking the aid of a series of astronomical occurrences, which, viewed not separately but in combination, appear to be fully sufficient for the production of this great winter of the ages. Among the facts referred to are, (1) variation in the obliquity of the earth's axis to the plane of the ecliptic; (2) variation resulting from the advance of the perihelion in connection with the precession of the equinoxes; and (3) variation in the eccentricity of the earth's orbit around the

sun. Intense cold being produced by a combination of cosmical agencies, the formation of an ice sheet of vast extent would naturally follow, especially if there were abundant moisture. The fact of intense igneous activity, near the close of the tertiary times, suggests the occurrence of immense evaporation, and thus a source of aqueous supply. Under these conditions an ice sheet might be readily formed. Great cold prevailing on its northern limits, and serving as a barrier to its motion in that direction; there being at the same time a partial melting of its southern face; meanwhile the waters from the wasting snows on its surface percolating the icy mass; there also being contractions and expansions consequent upon alternations in the temperature; all these being connected with the gravitating force of a mass from five thousand to ten thousand feet in thickness, motion toward the south would inevitably result on a horizontal surface, and much more if there were even a slight southward inclination of the country. Under these circumstances there must have been an instrumentality fully able to plane, smooth, and striate the rocky floor of the country, as it now appears, and thus to account for the débris almost everywhere met with in great abundance.

But, if there were no elevation of the continent, how are we to explain the various phenomena which are regarded as evidence and results of a higher level of the land? — for instance, the occurrence of pot-holes in places apparently never traversed by torrents; the formation of fiords; the existence of submarine river-channels, as those extending from the existing mouths of the Hudson and of the Connecticut; or the fact of sub-aërial deposits, as mud-flats, now found beneath the level of the sea. It is well known that, when glaciers meet with obstructions, breaks (known as *moulins*) occur in them; that, the snows melting on the surface of the ice mass, streams are formed which flow into those breaks, and thus become torrents and cascades, which wear pot-holes in every respect similar to those requiring explanation. This being the case, the result in question might have been produced, during the glacial period, without an elevation of the northern regions. Again, it should be remembered that an immense ice sheet moving seaward must, in displacing the waters along the shallow margin of the ocean, do its legitimate work of erosion beyond the present shore line, and that thus old depressions might be deepened, while new valleys and fiords would be formed, as well as the so called submarine river-channels, which remain to this day. Accordingly,

all this erosion could readily take place, without an uplift, even if the sea were at its present height. But this suggests a question: Whence came the vast ice sheet? Undoubtedly, I answer, for the most part from the ocean. Thus its waters must have undergone a great depression, perhaps one of several hundred feet; and this enables us to account for the mud-flats and other like deposits now beneath the surface of the sea. They were probably laid down when the ocean was at a lower level than it is to-day.

It has been, moreover, thought necessary to suppose that a depression of the continent finally followed its conjectured elevation. The land having been lifted up, it must be got down again in some way, in order that there might be a return of warmth, and things be substantially as we now find them. Now marine organic remains seem to attest a limited depression, in a few places one of some five hundred feet. But so slight a submergence of the land, there being upon it an ice sheet thousands of feet in thickness, could not cause a return of warmth; meanwhile the cosmical agencies, already referred to as the cause of the intense cold, would in due course of time, by a reversal of the direction of their influence, be abundantly sufficient to produce a return of warmth. A summer of the ages thus coming on, the ice sheet gradually melting on its southern border must retreat northward. And the waning of the glacial mass would be accompanied by results which require an extended, though they can now receive only a slight explanation.

The ice gradually thawing, the immense mass of detrital matter which lay beneath it, and is known as typical drift, would be by degrees laid bare, and left substantially as we now find it. In this view a resort to a depression of five thousand or six thousand feet, and to iceberg agency, is unnecessary. Indeed, Arctic icebergs could not furnish the material which makes up New England typical drift, since it is for the most part of local origin. No more could bergs from the White Mountains have supplied it; for it is a continuous sheet, having a uniform glaciated character, and spreading over vast areas lying far to the north no less than to the south of these mountains. So icebergs could not have deposited it, because, as they slowly wasted, the particles of matter must have been scattered by the flux and reflux of the tides, and thus to a large extent stratified. Again, from the southern border of the wasting ice sheet, floods of water would flow, working over and remodelling portions of the detrital masses, bearing some of the

finer material southward, and laying down those deposits known as modified drift. These constitute in part the terrace-formations, which usually slope with the rivers along which they occur. In exceptional cases there were barriers obstructing the waters; thus were formed ponds and lakes, in which deposition took place in more nearly horizontal layers. Finally, from the wasting of the ice sheet the surface of the ocean must have been elevated, its waters spread over the lower levels of the still partially depressed lands, laying down beds containing marine organic remains, which to-day bear witness of what was perhaps a slight depression. In due time, after the disappearance of the ice, the continent would resume its normal elevation, the brackish waters of the ocean be excluded from the estuaries, and all things come gradually to take the position which they hold to-day.

In conclusion, it may be asked whether the explanation suggested be not in consistency with the facts, and thus whether we ought not to accept it, rather than arbitrarily to resort to the assumption of a vast continental elevation and depression, which, if not disproved, is at least wholly unsupported by positive evidence.

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7. Remarks on the Relative Age of the Niagara and the so called Lower Helderberg Groups. By A. H. Worthen, of Springfield, Illinois.

Recent investigations have developed certain facts bearing upon the question of the relative age of the above-named groups, which we desire to present in a brief manner for the consideration of those who are especially interested in stratigraphical geology.

In Northern and Western Illinois, from the mouth of the Illinois River northward to the Wisconsin line, the Upper Silurian division of the palæozoic series is represented by buff, gray, or yellowish-gray dolomites, sometimes in remarkably even beds, as at Joliet and Grafton; and at other localities, by concretionary masses, with but faint traces of stratification, as at Bridgeport, near Chicago, and at Port Byron and Leclare, at the head of the Upper Rapids on the Mississippi River. They range in thickness from seventy-

five to three hundred feet, and directly overlie the shales and argillaceous limestones of the Cincinnati group of the Lower Silurian series. These dolomites are quite fossiliferous, and afford many characteristic Niagara species, among which we may mention *Pentamerus oblongus*, *Spirifer radiatus*, *Calymene Blumenbachii*, *Caryocrinus ornatus*, *Orthoceras undulatum*, etc. From the Bridgeport locality alone, nearly one hundred species of fossils have been enumerated, a large number of which are specifically identical with those found in the Niagara beds of New York and Canada; and, so far as we are aware, all Western geologists are agreed in considering these dolomites to be the stratigraphical equivalents of the Niagara group of New York.

In Southern Illinois we find these dolomites replaced by a series of silicious and argillaceous limestones, forming a group two hundred and fifty feet or more in thickness, which, like the dolomites of Northern Illinois, rest directly upon the Cincinnati group, and are immediately succeeded by Devonian strata. At the base of this group of silicious limestones there are some reddish mottled beds, from ten to twenty feet in thickness, that in color bear considerable resemblance to the Medina sandstone of New York; and these mottled limestones pass gradually into the buff and gray silicious beds that constitute the upper and main portion of the group. Fossils are rare in the lower portion of the group here; but the mottled limestones contain some *Orthoceratites*, and joints of large *Crinoidea*, while the middle and upper portions are locally quite fossiliferous, and have afforded many of the characteristic species of the so called Lower Helderberg group, among which are the following: *Orthis subcarinata*, *O. oblata*, *Cœlospira subcarinata*, *C. imbricata*, *Spirifer per-lamellosus*, and *Platyceras spirale* of Hall, and *Acidaspis hamatus* of Conrad, together with species closely resembling, if not identical with, *Merista princeps*, *Platyceras pyramidatum*, *P. unguiforme*, *P. incile*, and *P. multistriatum* of Hall.

In the first volume of the "Report on the Geological Survey of Illinois," these silicious limestones of the southern portion of the State, and the dolomites of Northern Illinois, were regarded as the stratigraphical equivalents of the Niagara group, and were included together as representing a single division of the Upper Silurian series; but subsequently in a corrected section of the Illinois strata, published in the introduction to the second volume, we were induced, from the dissimilarity of the fossils from the different sec-

tions of the State, to regard the silicious limestones of Southern Illinois as the representatives of a higher geological horizon, and therefore placed them above the dolomites of the northern part of the State, as the equivalents of the so called Lower Helderberg group. We are now, however, fully satisfied from a further examination of these Upper Silurian strata, over a more extended region, that our first conclusion was correct, and that these silicious limestones and dolomites represent the same geological horizon, and that the difference in the specific character of their fossil contents is entirely due to the changes in the oceanic conditions under which they were deposited, and not to the different ages of the sediments themselves.

South of the Ohio River, these Upper Silurian strata are found well exposed in Tennessee, in the counties of Wayne, Perry, and Decatur, on the Tennessee River, outcropping over a wide area, and affording numerous species of fossils in a fine state of preservation. The base of the group here consists of reddish and mottled limestones, very similar to those in Southern Illinois, and contain *Orthoceras undulatum*, and joints of large crinoids in great abundance. These red limestones are succeeded by a series of greenish-gray shales, and shaly argillaceous limestones, containing *Caryocrinus ornatus*, *Calymene Blumenbachii*, *Sphærexochus mirus*, *Platyceras Niagarense*, *Pentamerus oblongus*, *Orthis hybrida*, *O. elegantula*, etc., associated with such Lower Helderberg forms as *Pentamerus galeatus*, *Spirifer per-lamellosus*, *S. macropleura*, *Merista lævis*, *Rhynchonella ventricosus*, and many others, showing that the fossils of these so called groups are here intermingled through the same strata, confirming what we had already assumed to be true in Illinois, that the Upper Silurian beds of the West constitute but a single group, and consequently that the term Lower Helderberg, as applied to a group distinct from the Niagara, is superfluous. We recollect that, on visiting the locality of these so called Lower Helderberg limestones in the Schoharie Valley some years ago, we observed these limestones resting immediately upon undisputed Lower Silurian beds there; and, in explanation of their occurrence in this apparent abnormal position, we were told that the Niagara group was supposed to have thinned out to the eastward, and that these Lower Helderberg limestones took their place. But is it not quite as probable that there has only been a change in the lithological character of the beds in their eastern extension in New York, resulting there, as in Illinois, in a decided

change in the specific character of the fossils which they contain, and that the Upper Silurian beds at Schoharie are the exact equivalents of the Niagara shales and limestones in the western part of the State?

To recapitulate, then, the facts as they are presented in the West; we find that the dolomites of Northern Illinois contain only Niagara fossils, and the silicious limestones of the southern portion of the State contain only those considered characteristic of the Lower Helderberg group; while the beds in Tennessee, occupying the same stratigraphical position with the dolomites and the silicious limestones of Illinois, have Niagara and Lower Helderberg fossils intermingled indiscriminately through the strata. Hence we conclude that the so called Lower Helderberg group has no real existence as a distinct group of Upper Silurian strata, and that the name, being superfluous, should be dropped from the nomenclature of the American rocks.

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8. The Distribution of Maritime Plants in North America A Proof of Oceanic Submergence in the Champlain Period. By C. H. Hitchcock, of Hanover, N. H.

(Abstract.)

American Botanists have frequently recorded the presence of maritime phenogamous plants in the interior of the continent, and have commented upon the singularity of the circumstance. For example, Prof. J. A. Paine, Jr., in the "Regent's Report of the New York State Cabinet," for 1865, enumerates *Juncus Balticus* among the plants of Genesee County, at a locality over three hundred feet above Lake Ontario, and twenty miles south of it, associated with *Zygadenus glaucus* and *Solidago Houghtonii*, found only on the north shore of Lake Michigan. It is a seaside plant, native in Northern Europe and our own northern coast. "For its introduction to the great lakes it is just as dependent on the ocean as are *Ranunculus Cymbalaria*, *Atriplex hastata*, *Salicornia herbasea*, *Najas major*, *Ruppia maritima*, *Trigoclin maritimum*, *Juncus bulbosus*, *Scirpus maritimus*, and *Spartina stricta*, for their existence at Onondaga Lake, and *Lathyrus maritimus* on the banks of Oneida

Lake." He then conjectures that in some past geological period the land was submerged, and the ocean extended into the interior.

In the "Canadian Naturalist," for May, 1867, A. T. Drummond, B.A., LL.B., sets forth similar facts, and mentions twenty species of maritime plants that have been found in the interior. He refers the origin of this distribution to the presence of salt water in the great lakes in the Post Pliocene or Champlain period, subsequent to the glacial drift. As the waters gradually became fresh, some of the species would be exterminated, and others become reconciled to the changed conditions, and remain as monuments to this ancient oceanic prolongation into the interior of the continent.

With such conclusions all judicious reasoners must agree. I am not aware that any geologist has ever before touched upon this argument for submergence, and therefore am warranted in bringing a few facts and conclusions before the Geological Section. We have been accustomed to rely upon the presence of various marine animals and sea-weeds to show the former extent of the ocean, and, wherever these decisive evidences did not occur, have properly regarded ancient submergence as problematical, if not impossible. If we accept as truth the statement that maritime plants depend upon the proximity of salt water for their introduction into any country, then we cannot resist the conclusion that the ocean formerly penetrated the continent as far as Minnesota in the Champlain period. The submergence thus indicated was not of an earlier date, since the glacial cold must have destroyed all the temperate vegetation existing in the Pliocene period.

The best geologists have hitherto been unwilling to admit a submergence in the Champlain period greater than five hundred feet, and have fixed the inner oceanic limit near Lake Ontario, where the marine remains cease, and the "Erie clays" and other alluvial deposits commence, containing only fresh water fossils. As Lake Superior is 638 feet above the ocean, and the maritime plants surround its shores, there is an argument for a submergence, at least to the depth of its surface, and probably to the height of its terraces, so that we may add 330 feet to the altitude of the lake. This would give nearly one thousand feet, which corresponds well with the known height at which marine shells have been found in Arctic America; viz., one thousand feet on Cornwallis and Beechey Islands.

I have made inquiries of many of our botanists for catalogues of

plants along the Great Lakes and the Hudson River Valley, and present the following summary of the results obtained. The general distribution of the species is first given according to Gray, N. signifying their occurrence north of New York. The Canadian species are given on the authority of Mr. Drummond; Western New York, Prof. Paine; Lake Erie, Dr. T. C. Porter, of Easton, Pennsylvania, and Dr. J. S. Newberry; Lakes Michigan and Huron, Prof. A. Winchell, of Ann Arbor, Mich., and Dr. I. A. Lapham, of Milwaukie, Wis.; Lake Superior, after Porter, Drummond, and Winchell; Minnesota, after Lapham; Lake Champlain and Hudson River, on authority of C. H. Peck, of Albany, N. Y., and Miss Shattuck, of South Hadley, Mass. These gentlemen, and also Dr. R. H. Ward, of Troy, N. Y., have furnished, besides these lists, valuable suggestions in respect to the value of the inferences to be derived from the catalogues. The asterisk indicates the occurrence of the species at the locality specified.

There are seventy-nine species in this list. Of these, seven are noted as doubtful, since they may not be confined in their range to the seashore. The following may be legitimately added to the doubtful list: *Zygadenus glaucus*, Nutt.; *Solidago Houghtonii*, T. and G.; and *Corispermum hyssopifolium*, L. These occur in the interior, and not on the coast. The last, with *Naias major*, are not on the American, but flourish on the European coast. Add, also, *Lobelia Kalmii*, L.; *Rhyncospora capillacea*, Torr.; *Scleria verticillata*, Muhl.; *Scirpus pungens*, Vahl.; and *Polanisia graveolens*, Raf., — which, upon a careful examination, may prove to belong to the maritime type: certainly, so far as known, their distribution corresponds with that of the seventy-nine in the table.

Of this list, following "Gray's Manual of Botany," twenty-two are found on the coast north of New York, six south of the same, thirty (including *Juncus Vaseyi*, on the authority of Dr. Porter) occur mostly south of New England, and twenty-two are found along the whole of our eastern shore. Thirty-three of them, or only ten less than the whole number occurring on the coast north of New York, are found in the interior, distributed as follows: Lower St. Lawrence waters, five; Lake Ontario, nine; salt region of Western New York, seventeen; Lake Erie, seventeen; Lake Huron, twelve; Lake Michigan, fourteen; Lake Superior, fifteen; Minnesota, seven; Hudson River, only one; Lake Champlain, three; and Hudson's Bay, three.

From molluscan remains it is proved that the Hudson and

	Gray's Manual.	Lower St. Lawrence.	Lake Ontario.	W. N. Y. Salt Region.	Lake Erie.	Lake Huron.	Lake Michigan.	Lake Superior.	Minnesota.	Lake Champlain.	Hudson River.	Hudson's Bay.
Ranunculus Cymbalaria, Pursh	N.			•			•	•	•			
Cakile Americana, Nutt	N.				•	•	•	•				
Hudsonia tomentosa, Nutt.	Both.		•		•	•	•	•		•		•
Lechea thymifolia, Pursh	Both.											
Arenaria peploides, L	N.											
Spergularia salina, Presl.	Mostly S.											
" media, Presl.	"											
Sesuvium Portulacastrum, L.	S.											
Hibiscus Moscheutos, L	Both.			•								
Lathyrus maritimus, Bigelow	N.	•	•	•	•	•	•	•				
Phaseolus diversifolius, Pers.	N.			•	•							
Prunus maritima, Wang.	Mostly S.											
Crantzia lineata, Nutt	"											
Archangelica Gmelini, D.C.	N.											
Ligusticum Scoticum, L.	N.											
Aster flexuosus, Nutt.	Mostly S.											
" linifolius, L.	"											
Solidago sempervirens, L.	"											
Pluchea camphorata, D.C.	"							•				
Baccharis halimifolia, L.	"											
Iva frutescens, L.	"											
Borrichia frutescens, D.C.	"											
? Cirsium horridulum, Michx.	S.											
Plantago maritima, L.	N.											
Statice Limonium, L. var. **Caroliniana**	N.											
Glaux maritima, L.	N.											
Limosella aquatica, L.	N.											
" var. tenuifolia	N.											
Gerardia maritima, Raf.	Both.											
Mertensia maritima, Don.	N.											
Sabbatia calycosa, Pursh.	S.											
" **stellaris, Pursh.**	Mostly S.											
" **gracilis, Salisb.**	"											
" **chloroides, Pursh.**	"											
Blitum maritimum, Nutt.	N.							•	•			
Atriplex patula, L.	Both.	•	•	•								
" arenaria, Nutt.	Mostly S.											
Salicornia herbasea, L.	Both.			•				•	•			
" Virginica, L.	Mostly S.											
" fruticosa, L.	"											
" var ambigua	"											
Sueda maritima, Dumortier	Both.											

	Gray's Manual.	Lower St. Lawrence.	Lake Ontario.	W. N. Y. Salt Region.	Lake Erie.	Lake Huron.	Lake Michigan.	Lake Superior.	Minnesota.	Lake Champlain.	Hudson River.	Hudson's Bay.
Salsola Kali, L.	Both.										•	
Amarantus pumilus, Raf.	Mostly S.											
Acnida cannabina, L.	"											
Polygonum articulatum, L.	Both.		•		•	•		•				
" maritimum, L.	Mostly S.							•				
Rumex maritimus, L.	"		•				•	•	•			
Euphorbia polygonifolia, L.	Both.		•		•	•	•					
Myrica cerifera, L.	Both.				•							
Naias major, All.	Eu.			•		•	•					
Zostera marina, L.	Both.											
Ruppia maritima, L.	Both.			•		•	•					
Trigoclin maritimum, L.	N.	•	•	•	•	•	•	•	•			•
" palustre, L.	N.	•	•	•	•							•
Juncus Balticus, Pethard	N.				•	•	•	•				
" Rœmerianus, Scheele	S.											
" Gerardi, Loisel	N.			•								
" Greenii, O. and T.	N.											
" Vaseyi, Engelm.												
? Cyperus Grayii, Torr.	N.											
Scirpus Olneyi, Gray	Mostly S.									•		
" Torreyi, Olney	"											
" maritimus, L.	Both.			•	•	•	•					
Eleocharis quadrangulata, R. Br.	Mostly S.			•	•							
" olivacea, Torr.	"			•	•							
? " rostellata, Torr.	"											
? " melanocarpa, Torr.	"											
Vilfa Virginica, Beauv.	S.											
Calamagrostis arenaria, Roth.	N.	•	•		•			•				
Spartina polystachya, Wd. Muhl	Both.											
" juncea, Willd.	"											
" stricta, Roth.	"			•								
" var. glabra												
" do. var. alternifolia	"			•								
Glyceria maritima, Wahl.	"											
" distans, Wahl.	"											
Brizopyrum spicatum, Hook.	"											
Uniola paniculata, L.	S.											
Tricuspis purpurea, Gray	Mostly S.				•							
? Hordeum jubatum, L.	Both.				•		•	•	•	•		
? Leptochloa fascicularis, Gray	Mostly S.			•		•	•					
? Cenchrus tribuloides, L.	Both.				•	•	•	•	•			

Champlain Valleys were covered by salt water in the period now under consideration. The proof of submergence, from the occurrence of maritime plants, is very meagre, only four species appearing on the list. It is possible that future researches may add to the list, though not in large numbers, after the researches of Oakes, Tuckerman, Torrey, Zadock Thompson, and Peck. It may likewise be observed that the Lower St. Lawrence furnishes fewer species than the borders of the Great Lakes. These deficiencies were so patent that Mr. Peck, in his reply to my inquiries, regarded "the connection between the maritime plants of the region of the Great Lakes with the Atlantic Ocean, by intermediate stations, as not well shown." Is it not possible that these breaks in the connection are proofs of the correctness of our theory? If the continued existence of these plants about the lakes is due to the presence of large bodies of water, even in the absence of salt, then we should not expect to find them remaining along the narrow Champlain, nor the still narrower Hudson River, nor, to a large extent, the St. Lawrence. The conditions are not favorable to their preservation. Furthermore, if the species were equally distributed from the ocean into the interior, or especially if they became fewer in number the farther they penetrated the continent, it might be said that they had migrated since the Champlain period, even to Minnesota. Hence what might appear destructive of our theory is, in reality, a strong argument in its favor. These considerations were forcibly set forth in a private communication from Dr. Ward.

It might be said by some that the plants in the salt regions of Western New York existed there naturally on account of the presence of saline matters in the soil. This circumstance will not, however, explain their origin. During the glacial period all life was destroyed by the intense cold. Hence the salt-loving plants disappeared. With the return of the warm temperature the plants could not return by an overland emigration. They could return only by a gradual migration along a shore line, whether salt or fresh, unless it be supposed plants were created for this special locality. The latter supposition is untenable, since a special creation is not required to explain the distribution of the other plants in the Northern States, and we cannot suppose there would be any difference in the manner of the introduction of the two classes. Once introduced, the salt-loving plants would find a congenial habitat, and would not disappear, even after the removal of the estuary.

There is hardly a possibility that the seeds of these plants could have been preserved in the ground during the long ages of glacial cold, and revivified after the return of warmth. Besides, the glacier, in ploughing out the valleys, would have transported these seeds far to the south, and fresh débris from the north would have covered up the briny exudations.

Botanists have described many maritime plants from the salt regions of the Rocky Mountains. These are the descendants of those which were introduced by oceanic migrations in cretaceous or tertiary times; and, as the glacier never covered them, they have continued uninterruptedly to our times.

The distribution of certain forms of animal life confirms our theory. As stated in the President's address, a species of marine crustacean has been found recently by Dr. Wm. Stimpson, by dredging in the waters of Lake Michigan. Girard describes a fish from these northern lakes, *Triglopsis Thompsoni*, all whose affinities are marine. Add to these the oft-quoted instance of marine insects found on Lake Superior by Dr. Leconte, and a parallel case of the discovery of two species of *Mysis* in Norwegian lakes. Also, according to F. W. Putnam, Director of the Peabody Museum, in Salem, Mass., the fishes found in Lakes Champlain and Erie are so much alike, though widely separated, that an ancient salt water connection is needed to explain their present isolation.

In conclusion, the importance of observing and recording the localities of plants and animals may be clearly seen. Botanists, Zoölogists, and Geologists have worked apart. They should do so no longer, since the distribution of living plants and animals may throw light on other geological speculations than the one herein set forth.

9. LAKES AND LAKE REGIONS. By S. J. WALLACE, of Keokuk, Iowa.

Lakes.

LAKES are basins of limited area, filled with water which does not flow out as in a body. They have great variety of shapes. Their figures are usually formed by unions of curved lines, with some internal and some external projections, capes, and bays, and some angular points.

Lakes fill depressions of surface, which are of four kinds: 1st, Basins of Depression of Strata; 2d, Basins of Faults; 3d, Basins of Erosions; 4th, Basins of Clefts. These kinds have usual ranges of size in the order named, decreasing to the last.

The sizes of lakes vary from the smallest permanent surface water to several hundred miles in extent. Bodies of water which are not permanent are ponds. And bodies which have no depth are swamps.

Lakes have two characters: Fresh and Saline. Fresh lakes are those which have a permanent drainage from the edges of their rims at a certain height, by which their salts are carried off. Salt lakes have no drainage by which their salts are removed. The salt lakes are of two sorts: those connected on a level with the sea, and those separated.

The term *lakes*, alone, usually conveys the idea of limited size and fresh water. *Salt lake* is a term for a saline body of limited size. The term *sea* usually conveys the idea of those of a larger size, and with salt water. The terms *bay* and *loch* relate to those connected with the sea.

Lakes, with fresh water, are elevated to a greater or less extent above the sea to which they discharge. Their outlets must gradually wear down with time. Old lake-beds, forming valleys drained by worn-down outlets, are very common features in physical geography.

Lake Regions.

There are various parts of the world where lakes are a common feature, and other parts where they are entirely absent. There are also other regions where salt lakes are a feature of occurrence.

The regions of salt lakes or inland seas appear to be of a dry

character, where the amount of rain is too small to fill the basins, and wear down outlets. The regions of no lakes appear to be where all basins have worn out drainage ways, although they may still have special submerged tracks, sometimes, where no fall or elevation exists to enable the wearing down to take place for drainage. The regions of lakes are where lakes, although often greatly elevated, and having continuous overflows, have not worn their water-ways sufficiently for drainage. The exact relations between the regions of lakes and no lakes does not appear to be well determined. They do not appear to be dependent on any single character of physical structure; for their division lines sweep alike over plain and mountain regions, without regard to any single feature of geological formation.

To enable the subject to be intelligently studied, the several regions of North America and Europe may be pointed out, as there are broad fields in each.

In North America.

The lake region of this continent covers the northern half of its surface, down to a varying line about 42° and 43° N, from the Atlantic to 100° W., at which point it sweeps northward into British America, and descends again west of the mountains to near the Columbia, including all northward, and excluding all southward of an almost definite line.

The no-lake region includes all the south half, east of the Rocky Mountains. West of this line, from the Columbia south to the Isthmus of Darien, is a region in which inland seas or salt lakes are found, along with, usually, no-lake features.

North of the no-lake line from the Atlantic west, over Maine, New Brunswick, Canada East, Canada West, Northern New England, and New York, Wisconsin, Michigan, Northern Iowa, Minnesota, and Winnepeg, lakes are spread broadcast, great and small, from the Superior down to an acre in extent. Good detail maps show them as a general feature everywhere; although, of course, there must be spaces less marked than others, especially toward the south line. The one State of Minnesota is estimated, on good basis, to have ten thousand lakes; and Maine and Canada are probably nearly as full. This region is remarkable for its general elevation.

South of this line the presence of a fresh lake is a remarkable feature, although old lake-beds, with worn outlets, exist over this

region, especially in the Alleghany region; and it may be a general feature, if it were noticed.

In Europe.

The lake region line is about ten degrees further north. It covers the north-west fourth of Europe, including Iceland, Ireland, Scotland, Germany, south to Central Prussia, Denmark, Norway, Sweden, Finland, and eastward into Russia to Moscow. The line nearly follows the 52° to 53° N., with a curve north to reach the 40° E. toward the North Sea, and then north. The features in this area are similar to those of America; perhaps fully as much marked with lakes and ocean inlets, which are often associated.

There is another more limited lake region in the Alpine District, extending eastward over Switzerland, and on to the Danube in Hungary, from 6° to 18° E., and from near 45° to 48° N.

The rest of Europe, about two-thirds of the whole, is a no-lake region, similar to the American.

In the south-east corner of Europe, extending more widely into Asia, south and east, is the Sea or Salt Lake Region, also analogous to the American.

Causes of Difference.

The reason for the appearance of lakes in such geographical regions, and their absence beyond, is a subject requiring more full study.

It is remarkable that the lake regions of both Europe and America occupy those portions of the continents most particularly supposed to have been subject to the glacial action; and also those where frost locks up action for a great period of the year. But the relation of these facts to the cause has not been yet clearly set forth.

In a proper study of lakes, as related to their causes of appearance, the first thing, of course, is to determine the kind of basin,—whether of curvature, of fault, or erosion, etc. Then there is the further question of their age and proximate cause,—whether the basins are geologically old, or incidents of any comparatively modern cause.

In regard to lake basins there are two points of inquiry: as to whether their closures are, 1st, primitive, or innate; or are, 2d, proximate, as valleys closed by incidental causes, of which there

may be several, — as glacial action, subsequent eruptions, drift damming by drift-wood, action of beavers, irregular subsidence or elevation, etc.

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10. On the Evidence of a Glacial Epoch at the Equator. By James Orton, of Poughkeepsie, N. Y.

The Valley of the Amazon is highly interesting to the geologist, from its vast extent and its disputed origin. Probably no other region on the globe, of equal area, has such a remarkably uniform character. From the Andes to the Atlantic, and from the Falls of the Madeira to the Orinoco, scarcely any thing is visible but clays and sandstones.* Professor Agassiz was the first geologist of eminence to explore any considerable part of the formation. He ascended the river to Tabatinga (1,500 miles in a straight line); and he has well described the successive beds, of which he distinguishes ten. The chief, in the order of superposition, are: coarse sand, laminated clays of divers colors, ferruginous sandstone, and an unstratified sandy clay. Of these, the argillaceous portion is the most important, as it is the most extensive, the sandstone being reduced to isolated hills by denudation. The clays generally are very fine in texture, and without a pebble. They contain a large percentage of iron, but no trace of lime. There are, however, calcareous concretions, nodular or stalactiform, strikingly similar to the marly concretions noticed by Darwin in the Pampean mud. The argillaceous deposits are more conspicuous on the Upper Amazon, and the sandstones on the Lower. The whole formation dips gently to the east, and its total thickness is about eight hundred feet.

Professor Agassiz considers the valley a cretaceous basin, filled with glacial drift; in other words, that all these clays and sandstones were deposited underneath a gigantic glacier, which de-

* Professor Agassiz speaks of this clay formation as stretching over a surface of more than three thousand miles in length; but he is evidently led astray by the length of the Amazon, with all its windings. The width of the continent at the equator is only 2,100 miles.

scended from the Andes, grinding into fine powder the materials between it and the solid rock, and leaving an immense moraine across the mouth of the valley. To this theory we make the following objections: —

1. The theory is short of positive proof where we need the most unquestionable evidence. The confession is made, that "the direct traces of glaciers, as seen in other countries, are wanting in Brazil." There is not a trace of furrows, striæ, or polished surfaces.* The answer that the rocks are so friable, and disintegration in the tropics so rapid, as to render their discovery hopeless, is not entirely satisfactory. The granitoid rocks which border the valley, and the schists and porphyries on the slope of the Andes, ought to preserve some marks of the glaciation.† The pot-holes in the gneiss plains of Bahia, supposed by Hartt to have been formed by glacial cascades, are "exceedingly well preserved, and have smooth sides;" while all the plowings and planings of the gigantic glacier over the same rock have been utterly erased by disintegration! The stone structures of Brazil endure remarkably well, while the granite of Quebec exfoliates so rapidly in winter that oil is used to protect the buildings; yet there is no lack of striæ in Canada.

Boulders occur only along the eastern region: none have been observed in the great interior basin. This is a strange inversion: if a continental glacier moved down the Andes to the Atlantic, we would naturally look for porphyritic boulders scattered over the valley, and dwindling in number and size as we near Pará. We are suspicious, also, that these so called boulders have not travelled. The only genuine erratics seen by Professor Agassiz were found on the northern flank of Ereré: all the others turn out to be "boulders of decomposition." The boulders of Tijuca, in the Rio Province, described by Hartt, were not far-fetched: the majority are of gneiss on gneiss. Still they may have been the work of local

* Professor Hartt likewise acknowledges: "I have nowhere seen either polished or striated rocks."

† The eminent explorer, Dr. Spruce, describes the Casiquiari Region as "one great sheet of granite and gneiss. There is nowhere any continuous range of mountains or plateau, and (except towards its borders) the granite has been entirely denuded of the stratified rocks that once overlay it, and is now either naked or else overspread in some places with a thin covering of white sand, and in others (chiefly flats, hollows, and rifts) with a thick deposit of the fertile 'terra roxa,' or red loam (decomposed gneiss, mica-schist, etc.), which I have supposed to be lacustrine, but Professor Agassiz says is glacial drift."

glaciers. The Ereré erratics are hornblendic and without scratches: the lack of striation, however, is no proof that they are not true boulders.

To complete the glacial picture, it is asserted that a gigantic moraine stretched across the mouth of the valley, though, as Dr. Newberry says, "a moraine can hardly be formed by a glacier, except where there are cliffs and pinnacles along its course;" and as the absence of glacial inscriptions is attributed to disintegration, so it has been found convenient to say that this morainic wall must be looked for in the depths of the Atlantic.* It is worthy of remark, moreover, that fiords, which are conterminous with the drift of high latitudes, are absent from equatorial coasts. Thus we are called upon to believe in the existence of a tropical glacier, 2,000 miles in length, moving "for hundreds of thousands of years" over the continent, upon evidence which is singularly defective.

2. We object to the theory because the formation contains tertiary shells. Previous to the expedition of the writer across the continent in 1867, the vast clay beds along the Great River had not yielded a single fossil. In the words of Professor Agassiz, "tertiary deposits have never been observed in any part of the Amazonian basin." And it was on this negative evidence mainly, that the distinguished naturalist hazarded the conjecture that the formation was drift. But the banks of the Upper Amazon prove to be highly fossiliferous. At the confluence of the Ambiyacu with the Marañon stands the village of Pebas, about two hundred miles west of Tabatinga, long. 72°. The site is a level tract about fifty feet above the river; and the formation is wholly of those peculiar variegated clays, which we traced far up the Napo, and are continuous with the Tabatinga beds, and with those on the Lower Amazon, where they are overlaid by sandstone. Imbedded in these clays, several feet below the surface, and incontestably *in situ*, we discovered numerous small shells. They were examined by Mr. Gabb, of Philadelphia, who published† the following species: *Turbonilla minuscula*, n. s.; *Neritina pupa*, Linn.; *Mesalia Or-*

* It seems to us that, if "the waters of the lake were suddenly released," they would have exerted the most denuding force near the outlet; yet along the Lower Amazon we find vast remnants of the sandstone series, as those of Ereré, Obidos, and Almeyrim, while further west the waters seem to have made a clean sweep of it. No table-topped hills like Almeyrim are seen west of Manaos.

† Amer. Jour. Conch., vol. iv., p. 167.

toni, n. s.; *Tellina Amazonensis*, n. s.; *Pachydon obliqua*, n. s.; *P. tenua*, n. s.

Before leaving Pebas, we engaged Mr. Hauxwell, the experienced English collector, residing at that place, to search for other localities. In February, 1870, he reported a large deposit on the south side of the Marañon, thirty miles below Pebas, at Pichaua, just west of Cochaquinas.* The shells were larger and more plentiful than at Pebas, but were found in the same layers of red and blue clays, from six to twenty feet beneath the soil. A collection (in quantity about half a bushel) was received in August, and submitted to the eminent palæontologist, T. A. Conrad, Esq. His paper, published in the "American Journal of Conchology," Oct. 10, contained many additional species, and corrected some mistakes into which Mr. Gabb had fallen from lack of perfect specimens. The following is a complete list numbered in the order of abundance, No. 1 being the most numerous: †

GASTEROPODS.	CONCHIFERS.
5. Isæa (Mesalia) Ortoni, Gabb.	3. Pachydon tenuis, Gabb.
12. " lintea, Conrad.	2. " carinatus, Conrad.
9. Liris laqueata, Conrad.	1. " obliquus, Gabb.
8. Ebora crassilabra, Conrad.	6. " erectus, Conrad.
14. " bella, Conrad.	7. " cuneatus, Conrad.
15. Hemisinus sulcatus, Conrad.	11. " ovatus, Conrad.
13. Dyris gracilis, Conrad.	10. " altus, Conrad.
4. Neritina Ortoni, Conrad.	17. And the fragments of a singular bivalve, probably allied to Mulleria.
16. Bulimus linteus, Conrad.	

The *Neritina*, which Gabb made identical with the living *N. pupa*, proves to be a new species. The *Isæa Ortoni* is accompanied by an immense number of small, delicate shells, which Conrad considers its young. He thinks the genus is related to *Tricula*. *Liris* and *Dyris* probably belong to the *Melaniidæ;* and *Ebora* is presumed to be a fresh-water genus. Of *Hemisinus* and *Bulimus*, there was but one specimen each. *Pachydon* ‡ is the most important genus, the collection furnishing seven distinct species. Conrad makes it one of the *Corbulidæ*, though its spiral beaks are in

* Mr. Hauxwell writes that he has found similar shell-beds on the north side of the Marañon, about a mile inland, both east and west of Pebas, and also at Maucallacta.

† The type series is now in the New York State Geological Cabinet.

‡ As this name is too near *Pachyodon*, Conrad suggests *Anisothyris*. It had an internal cartilage in a pit behind the tooth of the right valve, exactly as in *Corbula;* and Meek is inclined to consider them identical. The only shell

marked contrast with those of *Corbula*. Some of the species attained considerable size, particularly *tenuis* and *erectus*. A specimen of the latter before us measures two by two and a quarter inches, and is packed with clay crowded with *P. obliquus*. All the specimens are remarkably perfect, except *Bulimus* and the unknown bivalve. The valves of the *Pachydons* are seldom separated, and scarcely ever broken, and none of the shells show the least abrasion. The *Neritina*, *P. tenuis*, and *P. carinatus* retain the epidermis, the first displaying various patterns of colored zigzag lines. Many species, as *Isæa lintea*, *Liris laqueata*, and *Dyris gracilis*, are exceedingly delicate, yet perfect. But Agassiz says the Andean glacier must have plowed the valley bottom over and over again, grinding all the materials beneath it into a fine powder. How did these shells escape during "the kneading process the drift has undergone beneath the gigantic ice plow"? The supposition that they may have been washed in from another locality must be rejected, for they are plainly in place, and none are waterworn. "It seems clear," says Conrad, "that they were not transported from a distance, but lived and died in the vicinity of the spot in which they are found." The shells are filled with the same bluish or drab sandy clay, "holding minute scales of mica, and frequently ferruginous," in which they occur. The *Pachydons* abound in the indurated and concretionary as well as soft parts of the formation.

Here, then, we have a large collection of shells from localities thirty miles apart, exhibiting seventeen species, all extinct, belonging to nine genera, only three of which have living representatives. The beds, therefore, cannot be later than the Pliocene. There is not one strictly marine genus: Gabb's *Tellina* turns out to be the young of *P. tenuis*. The deposit was probably of brackish-water origin. Only one specimen of the land-shell *Bulimus* was found, and this was about the only one in the collection which appears to have suffered fracture before deposition. The fact that all the parts are so orderly laid down — lignite, clays, and sandstones — points to a quiet formation, and not to a tumultuous flood or debacle. Any subsequent oscillation must have been continental, for the beds are without a sign of being unequally tilted or dislocated.

observed by Darwin, in the Pampean formation, was *Azara labiata*, D'Ors., one of the living *Corbalidæ*. It has no spiral beak. Several species of *Azara* (*Potamomya*) live in the brackish parts of the Amazon. *Corbulæ* were abundant in the early tertiary. See Annals of Nat. Hist. for Jan. and Feb., 1871.

It is quite plain that the Drift Theory of this formation must be abandoned. But Professor Hartt, to whom science is indebted for many minute and careful observations on the eastern border of Brazil, has propounded a new version. He thinks that the clays and sandstone are very late tertiary and marine; while the superficial, unstratified deposit, covering like a sheet the whole country, — plains, campos, and sierras, — is drift, the product of a general glacier.* It is doubtful if even local glaciers, of any great extent, existed on the mountains of Minas when they stood at a higher altitude than at present, for the same reason that glaciers are now absent from the equatorial Andes. But, for arguments already given and to follow, we certainly cannot believe in the existence of a vast glacier stretching from the Andes to the Atlantic.

3. We question the possibility of its formation. At the equator there is little variation of temperature. Pará is noted for its equable climate, varying little from 80°. At the Hacienda, on the slope of Antisana, 13,300 feet, the mean temperature in spring is 42°, summer 38°, autumn 40°, winter 41°. The snow-line on the equatorial mountains is, therefore, stationary; while the oscillation from summer heat to winter cold, in northern latitudes, gives rise to a variable snow-line. In the Alps, the variation from January to July is 34°. Now the snow-line at the equator remains throughout the year at 15,800 feet: at the latitude of New York it is only one half this. Therefore, to bring the snow-limit down to sea-level would require excessive cold.† But this more than polar reduction of temperature, and the uniform climate, would destroy the conditions necessary for the manufacture of the glacier, which must be constantly fed; and the supply depends on an abundant snow-fall, and this again on humidity. But an intense, unchanging winter would be a dry one. Besides, if a snow-field does not attain a temperature higher than zero, it can never become a glacier; for the particles are as incoherent as sand.‡

Moreover, if formed, we doubt its ability to move. The extra-

* Rounded and angular quartz pebbles cemented with ferruginous loam are seen in the Pebas district.

† In Europe, the most southern glacier which comes down to the sea is on the coast of Norway, lat. 67°.

‡ According to Hopkins, if blocks on the Jura were transported from the Alps by the agency of ice, the Alps must have been at least 6,000 feet higher than at present. But the lower the latitude, the higher the elevation needed. Who will estimate the altitude necessary to send an Andean glacier to the Atlantic?

ordinary, unbroken winter would prevent all movement; for this depends on repeated accumulations of snow and ice at the high sources, and on a change of seasons. All theories of glacier movement are based on the periodical partial liquefaction of the surface. The Alpine glaciers move twice as rapidly in summer as in winter. Then, too, the slope is insufficient. Forbes says a glacier must have an angle of 3° or 4°.* But between Pebas and Pará, a distance of 1,600 miles, the slope is only 8′ 5″, or about two and a half inches per mile; and from the tip-top of the Andes to the Atlantic, the inclination is 6′ 30″. We conclude, therefore, that if a sheet of ice ever spread from Cotopaxi to the mouth of the Amazon, it remained there, immovable as the mountains.

But difficulties lie back of this. As the length of a glacier depends greatly upon the speed with which it travels, it will be short in proportion as the angle of the slope is diminished. And, further, suppose the ice sheet formed and moving, what would be its flow? Even if its rate equalled that of the Mer de Glace, a boulder from the Andes would be over 20,000 years in reaching the Atlantic. But when we consider its feeble slope, and its retardation by the constant trade-winds, we may wonder if it ever completed its journey. Yet this Agassiz glacier is represented as doing a greater amount of work than the high latitude glaciers, grinding up and covering the vast basin with 800 feet of detritus, "the most colossal drift formation known." And again, all the slope of any consequence lies between the axis of the Andes and Pebas, a distance of 450 miles. In this abrupt descent (thirty-five feet per mile), it must receive momentum to carry it over an almost level plain of 1,600 miles. Why did it not plow up the silt, creating linear lakes like Como and Maggiore, which radiate at right angles to the strike of the Alps? Yet there is no appearance of excavation. The lagunes of the Napo are shallow ponds.

4. The existence of such a continental glacier at the equator would profoundly affect the life-history of the globe. As Newberry says, "Nearly all the fossil plants and molluscs of the strata deposited immediately anterior to the glacial epoch are undistinguishable from species now living in the same region." † If a

* The average slope of Mer de Glace is 14°; that of the Greenland glacier, 11°.

† In the opinion of De Candolle, subscribed to by Gray as likely, the greater part of the existing species of plants are older than the present configuration of our continent.

mantle of ice ever covered Amazonia, undoubtedly it had lateral branches descending the valleys of the Orinoco and Paraguay: there is a close similarity of the formation in these valleys to the Amazonian clay, which has resulted, we think, from a contemporaneousness, if not identity, of origin; and so low is the watershed, especially on the north, that the two river systems are joined by natural canals.* The glaciation of the whole earth at the same time is absurd, on biological and hydrological grounds; if, therefore, an equatorial ice-period occurred before or after the ice-period of the high latitudes, we must imagine the temperate regions converted by a change of climate into a conservatory for the rich and peculiar life in the tropics, which is an unwarrantable assumption. Polar types are now living in the intertropical oceanic area; so that their occurrence in any marine deposit is no evidence *per se* of the general extension of glacial action into tropical regions. And we may add that the almost total absence of typical North American plants in the highlands of the West Indies, and on the Andes of the equator, does not favor the theory of a glacial migration.

No continent has such a simple geological structure as South America. The monotony of its vast expanses is in strong contrast with the complexity of Europe. Witness the unparalleled extension of gneissic rocks from the Orinoco to Paraguay; the long, compact range of the Andes, so eminently porphyritic; and the extraordinary continuity and uniformity of the Llanos, Amazon, and Pampa deposits of ochraceous sandy clay. Yet we have much to learn before it will be wise to speculate on the geological history of South America. Darwin and Hopkins have given us sections across the Cordilleras; and it is much to be regretted that Professor Hartt has failed to give us a physical map, with geological sections and reliable altitudes. We need a careful section from Rio to Pará, and another from Manáos to the mouth of the Orinoco. Barometrical measurements are indispensable; but, so far as we know, the only consecutive observations with a mercurial barometer across the continent are those made by the writer in 1867.†

It is probably safe to say this much: that South America began

* The Casiquiari is only four hundred feet above the sea, or about two hundred above the centre of the Amazon basin.

† Published in Am. Jour. of Science, Sept., 1868.

with the table-lands of Guiana and Brazil;* that the subsequent upheaval of the Andes left estuary friths now marked by the three river systems; † that the Andes did not reach their present altitude until after the deposition of the Amazon formation, though it was a slow movement in mass, for the beds are nowhere unequally tilted or dislocated; ‡ that the archipelago on the north was formerly united to the southern continent, and that it has since been an area of subsidence; § and that simultaneously with this subsidence was created the low watershed which now separates the Amazon and Carribean waters.

* Bates has shown that the geographical distribution of insects indicates that Guiana was formerly an island.

† The sediments from these straits near the ocean would have a purely marine character; and Hartt observes that the clays and sandstones on the coast tie in with those of the Amazon.

‡ This certainly follows, if the Pebas and Pichaua shells prove to be early tertiary. The clay beds ascend the eastern slope beyond the village of Napo, which stands 1,400 feet above Pará, and in long. 77°. The red clay was not prominent on the Rio Napo till we reached long. 74°, and altitude of 550 feet, where there is a very high bank called *Puca-urcu*, or *monte colorado*, containing lignite, — *una mina de carbon de piedra*, says Villavicencio. This interstratified lignite is traceable eastward as far as Tabatinga. Darwin says that the Pampean formation was accompanied by an elevatory movement.

§ This is suggested by the South American character of the West Indian mammals and mollusks. There are palæontological reasons for believing (Proceedings of the Academy of Natural Science, Phila., 1868, p. 313) that the Caribbean continent was not submerged before the close of the Post Pliocene.

II. ZOÖLOGY.

1. On the Homologies of some of the Cranial Bones of the Reptilia, and on the Systematic Arrangement of the Class. By Edward D. Cope, of Philadelphia, Penn.

The great group of Reptilia may be considered as well circumscribed by the characters presented by their skeletal strutcure. They may be defined as vertebrates, with mandibular arch suspended from the cranium by the intervention of an os quadratum, or extra-auricular malleus; with the basis of the cranium formed of the cartilage bones, basisphenoid, sphenoid, and usually presphenoid; with a coracoid bone; and with metatarsals, metacarpals, second row (and usually first row) of tarsal and carpal bones distinct, and not coösified.

Within these limits there exists perhaps a greater variety of structure, in other respects, than in any other vertebrate class. The homologizing of the elements which present this variety is therefore a point not attainable without much study, while the homologizing of the same with their representatives in other classes is still more difficult. In the present essay a few points of this nature are, it is hoped, elucidated, especially with reference to the structures of the crania in the orders Ichthyopterygia and Anomodontia. Finally, the bearing of these and other points on the systematic arrangement of the class are alluded to.

1. *Homologies and Composition of the Cranial Arches.*

The bony arches which connect the facial part of the cranium with the posterior part of the brain-case, in nearly all Vertebrates, are primarily only two in number; viz., the zygomatic and the quadratojugal. They, however, form connections with each other and adjoining portions of the cranium, so as to complicate their determination, which is increased when one or other of their usual connections is, under these circumstances, atrophied or omitted.

The zygomatic arch takes its name from the only one which is present in the Mammalia; and that arch which is homologous with it throughout lower vertebrata must retain the name. It is then the arch connecting the maxillary with the squamosal (or squamosal part of the temporal) bone, and is therefore composed in large part of the malar.

The quadratojugal arch, as its name implies, is that which connects the maxillary with the quadrate bone. As the quadrate bone only exists as the malleus within the ear-chamber in the Mammalia, it is obvious that it cannot exist in that class. It can only be found in the vertebrata, from and including the birds, downwards. As the quadratum is projected below the squamosal, the position of this arch is always inferior to that of the zygomatic. It is composed normally of the malar (or jugal) and quadratojugal.

A third arch, which is especially characteristic of the Reptilia, connects the parietal bone with the superior extremity of the quadrate. The connection is accomplished by the intervention of the opisthotic or squamosal, or both.

The character of the arches existing in the different types of the vertebrata, above the Dipnoi, may be expressed schematically by the following table: —

I. Neither zygomatic nor quadratojugal arches.
  a. Without parieto-quadrate arch.
 Batrachia Urodela except Pleurodelidæ; Ophidia.
 Lacertilia Ophiosauri and Typhlophthalmi.
 Testudinata Chelydidæ.
 Mammalia Edentata (part).
  aa. With parieto-quadrate arch.
 Lacertilia Nyctisaura.
 Testudinata (Hydromedusa Platemys Rhinemys).

II. Quadratojugal only.
  a. Without parieto-quadrate arch.
  β. With quadratojugal bone.
 Aves.
  ββ. Without quadratojugal bone.
 Batrachia Anura in general.

III. Quadratojugal and zygomatic arches present.
  1. No postorbital arch.
 Batrachia Anura (Discoglossus).
  2. A postorbital arch.
  a. Without postorbital bone.
 Crocodilia.
  aa. With postorbital bone.
 Batrachia Stegocephali (Apateon).
 Ichthyopterygia.
 Rhynchocephalia (Sphenodon).
 ? Sauropterygia.
 Ornithosauria.

IV. Zygomatic arch only.
  1. With postorbital arch.
  a. With postorbital bone.

* Malar portion of zygomatic arch absent.
Lacertilia Varanidæ.
** Malar portion present.
Lacertilia in general.
Anomodontia.
Sauropterygia (? all).
Testudinata in general.*
a a. Without postorbital bone.
* Malar portion wanting.
Batrachia Urodela Pleurodelidæ.
Pythonomorpha.
** Malar portion present.
Batrachia Gymnophiona.
Mammalia Quadrumana, Artiodactyla, Perissodactyla (part).
2. Without postorbital arch.
Mammalia Carnivora Proboscidia Perissodactyla (part), Cetacea, Rodentia, Edentata (part), Monotremata.

From the above table, it will be observed that each class, and sometimes single orders, present many or several of the various types of structure of the arches. These arches are more or less protective or fixative in their use; that is, they protect the orbit, the temporal muscle, or the oral cavity, or fix the quadrate and prevent its motion. As adaptive characters, they are thus those which define very subordinate representatives of all the orders.

From want of analysis, the proper determination of the arches has not always been made, and the identification of the component and adjacent bones vitiated. This is no doubt owing to the fact, that in many Reptilia, where the orbits are large, and the temporal fossa small, — *e. g.*, Ichthyopterygia, Crocodilia, etc., — the zygomatic arch makes a strong sigmoid flexure, leaving the quadratojugal to take the more direct course to its terminus. Thus Owen (Palæontology) homologizes the quadratojugal arch of Ichthyosaurus with the zygomatic of Mammals, and the true zygomatic with the temporal fascia of the same. In the same way (*l. c.*, p. 210), he homologizes the quadratojugal arch of Nothosaurus with the zygomatic, thus: "The lower one (*i. e.*, arch) is formed by the malar (27) and squamosal (28), the latter answering to the true zygomatic arch in Mammals." The figures obviously refer, in the cut, to the malar and quadratojugal bones; while the "mastoid"

* The postorbital is prolonged so far downwards in Chelone and Chelydra, as to look like a quadratojugal.

in this, as in other determinations of the same author, is the squamosal.*

In the same way Günther, in describing Sphenodon (Philos. Trans., 1867), calls the quadratojugal arch the zygomatic, and the zygomatic the "temporal arch," employing a new name to designate it. Stannius (Zootomie der Amphibien) appears to have correctly identified the zygomatic arch in Lacertilia, but erroneously in the Crocodilia.

Before proceeding to determine more exactly the homologies of the posterior cranial bones, I will describe the cranial structures of Ichthyosaurus and Lystrosaurus, as our literature appears as yet to be deficient in these points.

2. *On the Cranium of the Ichthyopterygia.*

Commencing with the foramen magnum and occipital condyle, as fixed points, the connections of the bones, as they succeed each other forwards, may be safely considered.

All four of the occipital elements contribute to the margin of the foramen magnum, the supraoccipital not being excluded as in Crocodilia, Anomodontia, etc. The external or lateral margin of both exoccipitals and basioccipital are excavated by a large foramen. The continuous margin of both between these points is united to a bone which extends outwards and upwards, and which contributes by its superior and inferior margins to the outlines of the foramina just mentioned. Exterior to these, from the basioccipital to near the apex of the supraoccipital, there are no bones suturally united, and there is a vacuity in this position not seen in any other Reptilian cranium.

From the exterior margin of the inferior foramen, a subcylindric bone extends outwards. It is contracted medially, and is not in sutural connection with any other. Immediately exterior to it is a flat subvertical bone, which, as it bears the articular condyle for the mandible on its lower extremity, is no doubt the quadrate. That it is such is also proven by the fact that it is anteriorly connected to the malar bone by a quadratojugal.

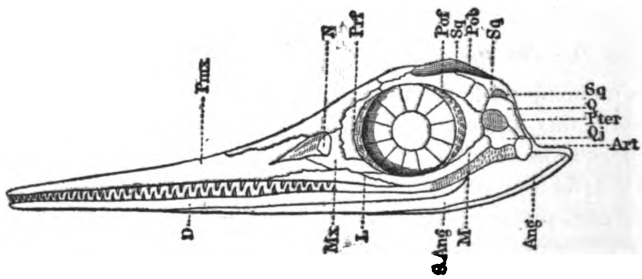
If we now turn to the lateral view of the skull, we observe the zygomatic arch, as determined above; *i. e.*, the superior of the two extending from the malar, and that which supports the postorbital arch. The bone which forms its posterior half must be the squa-

* This description, by the way, differs from Von Meyer's figures of Nothosaurus, where but one arch is represented.

mosal, not only on this account, but because, as in other Reptilia, it is articulated with the summit of the quadrate.

Turning again to the posterior face of the cranium, we may be in a position to determine the two bones described above as lying outside of the occipitals, and between them and the quadrate and the squamosals. The superior (Op. O, fig. 2) occupies the position of the "external occipital" of Cuvier, in the tortoise, both by its articulation with the exoccipital (Ex. O) and its direction towards the squamosal (Sq). Its separation from the supraoccipital, and contact with the basioccipital, are against this determination, yet

Fig. 1.*



the weight of these arguments is much less than that of those for it; and therefore I suppose it to represent that bone, which is the opisthotic of modern nomenclature.

The large foramen below the last, and exterior to the basioccipital, is in the position of the opening of the internal ear in the Lacertilia, as regards its relation to the latter bone, the opisthotic being separated from it by the extension outwards of the exoccipital. Its relation to the opisthotic is the same as that in the Cheloniidæ, where it is separated from the basioccipital by an inferior process of the exoccipital. It is probably the fenestra ovale; and, if so, the second bone in question (stap) becomes the *stapes*.

It is a question, however, to what extent this element is really

* Fig. 1.—Ichthyosaurus; lateral view (from specimen from Barrow, Leicestershire).

Pmx. . Premaxillary bone.
Mx. . . Maxillary.
N. . . . Nasal.
Fr. . . . Frontal.
Prf. . . Prefrontal.
Pof. . . Postfrontal.
Pa. . . Parietal.
L. . . . Lachrymal.
M. . . . Malar.
Qj. . . . Quadratojugal.
Q. . . . . Quadrate.
Pob. . . Postorbital.
Sq. . . . Squamosal.
D. . . . . Dentary.
An. . . . Angular.
Ar. . . . Articular.
S. Ar. . Subarticular.
Pter. . . Pterygoid.

stapes. In existing reptiles, it is only proximally expanded, and distally a slender rod terminating in the cartilaginous expansions called by Huxley* suprastapedial and extrastapedial; the latter being, as the same author shows, the support of the stylohyoid and other elements of the hyoidean arch, and with the suprastapedial the homologue of the incus. The expanded distal end of the bone marked *stap*, in Ichthyosaurus, looks as though it were the homologue of the cartilaginous expansions mentioned, in which case that bone becomes stapes and incus combined. This seems to us very probable.†

As a whole, this bone is in that case homologous with the hyomandibular of the Sharks and Teleostei. This has been pointed out by Huxley on embryological grounds to be the case with the incus. If the element (stap) in Ichthyosaurus represent both stapes and incus, the same is probably true of the hyomandibular.

Turning again to the squamosal, we find it appears to possess an extraordinary development. Besides forming the posterior portion of the zygomatic arch, as in other vertebrata, and forming part of the combination which supports the quadrate, as in Reptiles and Batrachia generally, it sends down behind the quadrate a plate for more than one-third the length of the latter to the superior margin of the stapes. Instead of joining the parietal or opisthotic at its posterior margin, it is continued inwards to near the apex of the supraoccipital, and bending forwards continues, in company with its fellow of the opposite side on the inner face of the temporal fossa, to a point above the middle of the orbit, where it unites suturally with what may be called the pari-

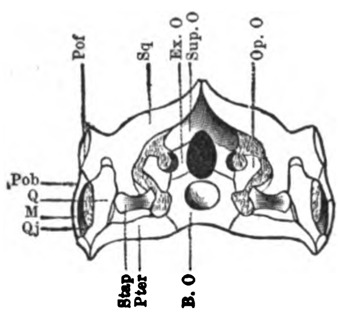


Fig. 2. ‡

* In a most valuable essay on "The Representatives of the Malleus and the Incus of the Mammalia" (Proceed. Zoöl. Soc., 1869, p. 391).

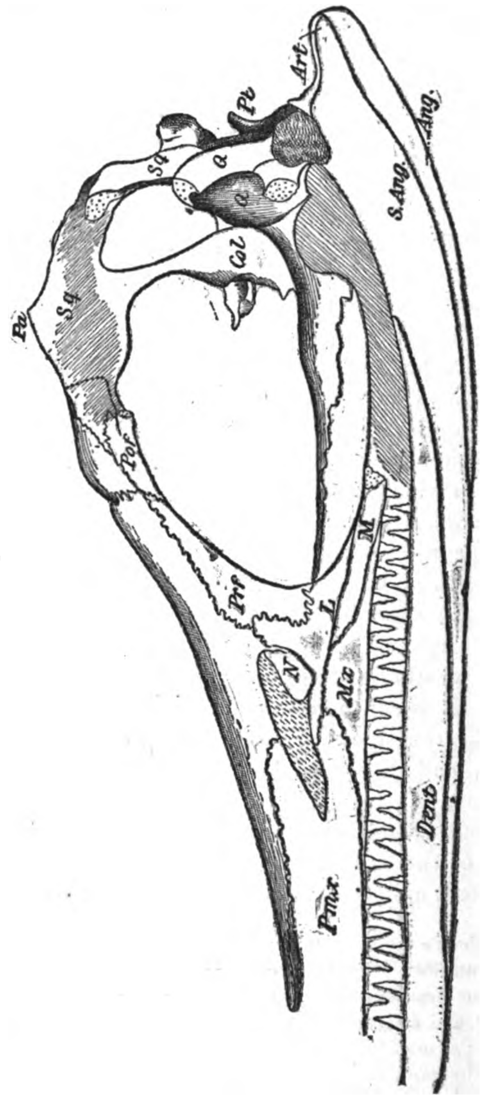
† In the serpent *Xenopeltis unicolor*, a superior process of the stapes (suprastapedial) is ossified, and a separate element at the end of the bone (extrastapedial v. stylohyal?) is also ossified. (See fig. 2.)

‡ Fig. 2.—Ichthyosaurus; cranium; posterior view. Lettering the same as in fig. 1, with the following additions:—

B. O. . . Basioccipital.
Ex. O. . Exoccipital.
Sup. O. Supraoccipital.
Op. O. . Opisthotic.
Stap. . . Suprastapedial, or hyomandibular.

etal. (See figs. 2, 3, Sq.) Though it cannot yet be asserted that this is one primary element, yet in the adult Ichthyosaurus there is

Fig. 3.



Cranium of Ichthyosaurus without arches.

Col, Columella. Pt, Pterygoid.

(The anterior extremity of the sphenoid is imperfect.)

no line of division to be discovered.* It will be seen later that the same structure exists in the Anomodontia and Sphenodon. It is not impossible that its anterior portion will be found to represent the element in Teleostei, called by Huxley, perhaps by error, Squamosal.

Returning to the external arches, we find the zygomatic is partially vertical, owing to the large size of the orbit and the shortness of the posterior region of the cranium, and that it is extended by a supernumerary bone not found in the Mammalia, for which I adopt the name given by Owen in this genus, of postorbital. (Figs. 2, 4, 13, Pob.) It is the temporal of the Testudinata of Cuvier, and one of the postfrontals of the Lacertilia of the same author. It is most errôneously called quadratojugal by Stannius, and by Günther, who follows him, in Sphenodon.

Anteriorly it articulates with the malar, here a long slender bone on account of the size of the orbit, and which, as usual, articulates anteriorly with the maxillary. Posteriorly the extent of the postorbital separates it from the squamosal, as is the case with some Lacertilia; while a short quadratojugal connects it with the quadratum, precisely as in the Crocodilia. This latter bone is the squamosal of Owen, who, on account of this erroneous determination, was compelled to apply a new name to the true squamosal, calling it "supratemporal." (See Palæontology, p. 198.)

Posterior to the postfrontal and postorbital, is an ovate bone connecting them with the squamosal. This is also peculiar to this order, and is the supersquamosal of Owen.

The postorbital arch is quite horizontal, and is composed of the postfrontal exclusively.

Turning to the superior aspect of the cranium, if we assume that the two posterior elements bounding the temporal fossæ are continuous with the squamosal, as has been above shown, there is no difficulty in determining the elements in front of them. Thus the undivided bone with large fontanelle near the posterior margin, bounding the squamosals anteriorly, would be the parietal. The posterior half of each of these bones is concealed by the anterior portion of the laminar squamosal as in Sphenodon: they descend beneath the latter to a point a little before the line of the middle of the temporal fossa. It scarcely touches its fellow on the median line behind the fontanelle. The general shape of the bone is

* I have since found a suture in two of our Ichthyosaurus crania, and Dr. Seeley states that that is the normal structure.

square. Each half is united to the bone behind it, except at the median suture, by a double squamosal suture, the squamosal bone sending a plate below as well as above it. Medially the suture is single and serrate. Suspecting that the bone here determined to be parietal might possibly be frontal, I searched for a bone posterior to it, beneath the prolongation of the squamosal, but without success. That the squamosal should contribute to the brain-case is apparently anomalous among Reptiles, though not among warm-blooded Vertebrates; but if we suppose the anterior plate to be the epiotic the difficulty is much lessened.

It might be objected that the position of the fontanelle was rather in favor of the determination of this bone as frontal, since it is, as in the Lacertilia, pierced in its posterior margin, and therefore probably, as in that order, included between the frontal and parietal. But in reply it may be asserted that the position of the fontanelle in the two orders most nearly allied to the Ichthyopterygia — *i. e.*, the Anomodontia and Rhynchocephalia — justifies the interpretation I have placed on this bone. Thus, in the former, it is pierced in the middle of the parietal with a suture extending from it to the occipital suture. In the latter it lies near the posterior margin of the parietal, so far as visible; for the latter bone is doubtless overlaid by the squamosals, as in Ichthyosaurus. Günther is probably correct in describing this median bone as parietal in Sphenodon.

The long paired bones, immediately anterior, which extend to near the middle of the muzzle, are the frontals. They extend to the premaxillaries, a junction only found in Reptiles with posterior nostrils, as Pythonomorpha, Varanidæ, etc., but common among Fishes. In Sphenodon the frontals are unusually produced in front.

Articulating with them on each side, and bounding the anterior and post and superior margins of the orbit, are the pre and postfrontals in their usual positions. The former almost excludes the latter from contact with the frontals, and leaves its connection with the parietal more extensive. Anterior to the frontals comes the elongate premaxillary. This of course bounds the nares in front; and as the latter are far removed posteriorly, in this order of Reptiles, the nasal bones have a posterior position also. The latter are much reduced in size, and have a very short suture with the frontals, being more extensively united with the lachrymal. They are entirely separated from each other by the anterior prolongation

of the frontal, and are chiefly to be recognized by their position as roofing the nares posteriorly, and their connection with the frontal. In one of our crania I observe that they are absent.

The maxillary is much reduced, in connection with this position of the nares. It is separated from union with the prefrontal by the large lachrymal, which extends to both the frontal and the premaxillary.

Such a determination of the bones of the roof of the cranium differs materially from that of Cuvier and Owen. The former (Ossemens Fossiles, Tab. 257, figs. 1–5, and p. 103, V, 2 plates) laid a wrong basis by assuming the bones (figs. 2, 3, Sq) to be the parietals: the parietals become then frontals, and the frontals are called nasals, the true nasals being entirely overlooked. Owen (Palæontology and Comp. Anat. Vertebrates) follows Cuvier in these points. Günther falls into error as regards the squamosal branches in Sphenodon, uniting them with the true parietal as parietals. The frontals he names correctly. The parietal in Sphenodon is shown by Günther's figure to be a simple medial element, as in Ichthyosaurus.

Having, however, observed a suture separating the squamosal from its supposed anterior plate in one young and one adult Ichthyosaurus cranium, it has occurred to me that possibly the specimen here described may have a coalescence of two elements really distinct. In that case the anterior bone will not be homologous with that in same position in Lystrosaurus, but may be, as usually stated, the parietal. The other bones in front of them would then retain their usual names, the supposed nasals (*n*) remaining without determination.

Turning to the base of the cranium of Ichthyosaurus, we observe that the palatines and ectopterygoids are broad, flat bones, whose exterior margin is in contact with the maxillary and malar to opposite the posterior margin of the orbit, flooring the latter (fig. 3, Ectp). The pterygoids, on the other hand, contract abruptly behind this point, and support the columella. They then expand to a degree unusual in the Reptilia, and extend over the whole space between the basioccipital and the quadrate, joining both closely, and projecting behind their posterior plane. Its margin is recurved as far as the stapes (Pt, figs. 1, 2, 3).

The columella is very stout at its point of contact with the pterygoid, and above it; but higher it contracts much, and then expands anteriorly into the parietal branch of the ? squamosal with

which it seems to be continuous, as I cannot see any suture separating them.

The basis cranii is incomplete, and is formed of basioccipital and basisphenoid. The latter (Cuvier, Oss. Foss., Tab. 257, figs. 12, 13) supports an alisphenoid on each side.

In considering the affinities of Ichthyosaurus as exhibited by the cranium, it may be premised that the structure of the limbs separates it as a very distinct order among Reptilia. The peculiar disposition of the squamosal is only paralleled among Anomodontia and Rhynchocephalia, and the character of the columella resembles only that of the former in its connections. The occipital elements have more the disposition of those of Sphenodon than of any other type, but there is a great difference in the position of the opisthotic. The arches are also those of the same genus, except that in the latter the quadratojugal is obsolete, or coössified with the malar. The structure of the front and base of the skull, and of the mandible, in Sphenodon, have no resemblance to those of Ichthyosaurus. The anteriorly unossified brain-case is that of several other Reptilian groups, while the presence of the alisphenoid furnishes a point of resemblance to the Crocodilia.

In general there are few points of affinity to the Crocodilia. The characters of the parietal bone are those of Sphenodon. The vertebræ are intermediate between those of that genus and the Lacertilia, and those of the Anomodontia; for the capitular and tubercular processes are confluent on the former, and widely separated in the latter, the tubercular being elevated to the neural arch. In the Ichthyopterygia they are separated, but both are on the centrum.

Thus the Reptilian affinities are divided between the Anomodontia and Rhynchocephalia, and are not very close to either. They are much less with the Lacertilia, and still less with the Testudinata and Crocodilia.

There are some extra-reptilian indications worth observing. The most important of these is the great extent of the pterygoids backwards and inwards, paralleling only in this some Batrachia, *e.g.*, Rana (fig. 21, Pt). The large size and form of the stapes are similar to that seen in Cœcilia. The posterior development of the squamosal is alluded to later, in the discussion of the homologies of that bone.

3. *On the Cranium of the Anomodontia.*

The bones of the superior and palatal surfaces of the cranium of the genus Dicynodon have been described by Owen; and the structure of the internal walls of the palatal and nasal cavities, with the occipital and mandibular bones, have been described by Huxley, from the Ptychognathus murrayi. The relations of the elements of the lateral walls of the brain-case, and the attachment of the os quadratum, have, so far as I am aware, never been made out. As these points are of the first importance in determining the affinities of the Anomodontia, I take the favorable opportunity for elucidating them, furnished by the very complete cranium of the Lystrosaurus frontosus, Cope, kindly placed at my disposal by Dr. E. R. Beadle.*

The maxillaries articulate posteriorly and externally with the ectopterygoid bone. This is vertico-oblique in position, its depth twice as great as its length. The pterygoid, which articulates with it posteriorly, is seen laterally, a flat hour-glass shaped bone, the anterior extremity embracing the ectopterygoid by a superior and an inferior process, whose articular faces are at right angles with each other. The contracted portion presents a longitudinal external angle, which disappears on the posterior part of the maxillary. At this point the pterygoid is arched upwards and inwards: it is then deflected outwardly and downwards to the extremity of the quadratum.

The relations of the pterygoid to the bones forming the anterior walls of the brain-case are of much interest, and throw great light on the vexed question of the homologies of the columella of the Lacertilian and Rhynchocephalian Reptiles. The adjacent bones may be first described.

The presphenoid is a flat lamina with arched superior margin, resembling that of the Crocodilia. It extends forwards in this species to the line of the frontal tuberosity. The inward and upward expansion of the pterygoid behind its median contraction, already described, appears to be in contact with the inferior margin of the presphenoid. It is not likely that this expansion belongs to the presphenoid, though it is difficult to perceive the suture. The expansion is subvertical. Posteriorly it expands backwards and outwards, forming the fundus of a deep subvertical groove, and unites suturally with the antero-interior margin of a bone,

* For description of this species, see Proceed. Am. Philos. Soc., 1870, p. 419.

Fig. 4.

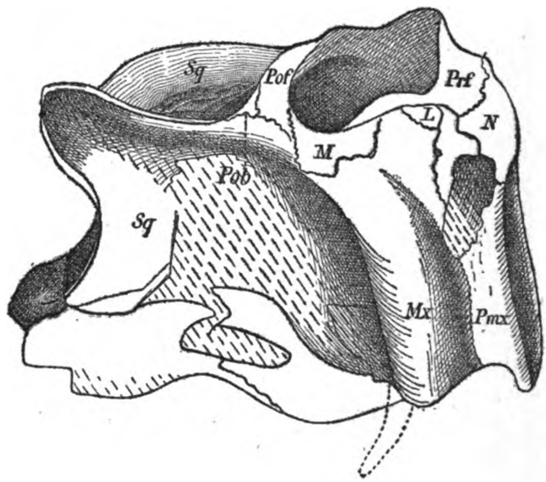
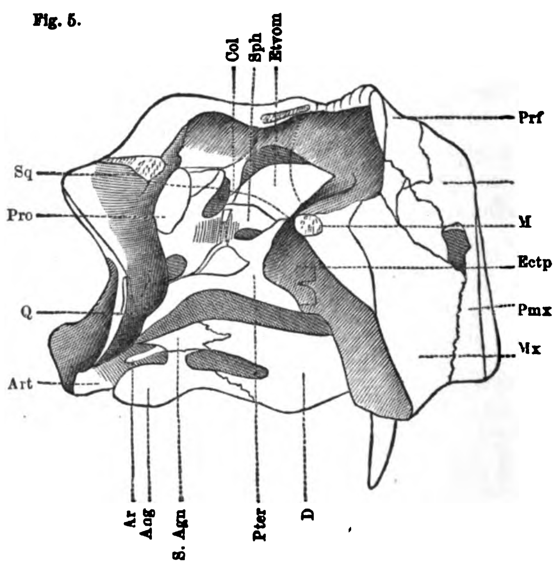


Fig. 5.



Figs. 4 and 5. — Lystrosaurus frontosus (from Cape Colony); profiles. (Fig. 5, diagram with arches removed.) Lettering as in figs. 1 and 2, with the following additions: —

Etvom. . Ethmovomerine.
Sph. . . . Sphenoid.
Pro. . . . Proötic.
Pter. . . . Pterygoid.
Col. . . . . Columella.
Ectp. . . . Ectopterygoid.
Subart. . Subarticular.

which I suppose to be the proötic. From the anterior and more horizontal portion of the pterygoid expansion, a thin laminar bone rises, which presents an angle outwardly. Superiorly and inwardly it appears to be continuous with a slender prolongation of the anterior angle of the parietal plate already mentioned. Not suspecting its existence, I destroyed a portion of this rod, in removing the matrix; but a piece from a point intermediate between the parietal and pterygoid extremities remains attached to the specimen in place. This element is, no doubt, the columella, whose existence in this group of Reptilia has not heretofore been suspected. It encloses a narrow vertical antero-posterior foramen with the presphenoid.

Two openings into the brain-case are visible: that between the parietal plates, common to most Reptilia, and the foramen, transmitting the fifth cranial nerve, the combined foramina ovale and rotundum. Another foramen is enclosed between the pterygoid and the element which bounds the proötic in front and below. A narrow bone with rounded edge extends from the superior origin of the columella, downwards and outwards to the proötic, bounding the foramen ovale above. It resembles the rod-like projection of the columella of Testudinata (see fig. 5), but that is below, not above, the foramen.

The exact composition of the suspensoria of the os quadratum is a little difficult to determine, owing to the obscurity of the sutures. The posterior parietal arches (fig. 7, Pa) are narrow and short, the posterior boundaries of the temporal fossa being chiefly formed by the squamosals. The latter commence on each side of the parietals, a little behind the anterior extremity, and form the overhanging margin of the temporal fossa, inwardly as well as posteriorly. The posterior plate of the parietal on each side is proximally enclosed between the squamosal and supraoccipital, then between the former and a thin laminiform bone, which extends laterally from the supraoccipital, and above the exoccipital. It is in contact with the squamosal for most of its length, but does not extend to opposite the zygomatic arch, and of course not to the os quadratum. This element, in spite of its exclusion from articulation with the quadratum, appears to be homologous with that which in Iguana extends from the same position to that articulation, and which is evidently homologous with the opisthotic of the Testudinata.

The squamosal is very largely developed in Lystrosaurus. Con-

tinuing round the temporal fossa, it sends forwards the usual zygomatic arch, and — what is noteworthy — unites with both postfrontal and malar, leaving the usual tripodal supplementary postorbital as a wedge-shaped plate, bounding the antero-inferior angle of the temporal fossa. The squamosal continues without interruption to the inferior extremity of the quadratum, concealing the latter entirely on a posterior view. I find no suture separating it from the superior portion already described, on either side of the cranium; and on reference to Owen's figure of Ptychognathus declivis,* I find that he found them continuous in that species. He calls this element the "masto-tympanic," which would be the Cuvierian nomenclature for opisthotic-quadrate of modern anatomists. I find, however, that it does not include the quadrate which is situated immediately anterior to it, and does not appear to contain the opisthotic, which, as already described, is distinct. It is in fact figured by Owen in Pt. declivis, and named parietal, the close squamosal suture separating it from the posterior arches of the latter bone not having been detected.

When the supposed quadrate bone is fractured, it is found to consist of two vertical plates, of which the anterior bears the narrow transverse articular face for the mandible, excluding the posterior one. This I take to be the os quadratum. Its width is not so great as that of the posterior plate or squamosal, and it does not ascend much more than half way to the zygomatic arch. Its superior margin appears to be received by the margin of the thicker superior portion of the squamosal, which somewhat overhangs it. I cannot trace its inner margin. A descending portion of the inner face of the squamosal approaches very near the posterior part of the pterygoid, and it is doubtful whether the quadratum extends interior to this point. The bony wall which appears below the proötic has been already alluded to as continuous with the pterygoid expansion, but it may represent the lateral processes of the sphenoid, or even part of the alisphenoid.

The squamosal or parietal sends down on each side a vertical plate, which terminates in a slender bony prolongation from its anterior margin. The plate is subquadrate, and twice as deep as wide antero-posteriorly. The osseous ethmovomerine septum extends posteriorly to between the anterior margins of these laminæ, and is prolonged inferiorly to the presphenoid, the suture with the latter extending beyond the anterior line of the above-mentioned

* In Proceed. Geol. Soc., Lond., xiv., Tab. 1.

laminæ. I can find no suture separating these plates from the squamosal above, and am therefore disposed to doubt whether they do not belong to these rather than to the parietals.

The ? epiotic is a subovate bone with truncate extremities, which has its long axis directed upwards and inwards. It is in contact with the parietal and the descending anterior plate of the squamosal, and inferiorly with the bone described in the next paragraph as proötic. It occupies a position similar to that seen in Sphenodon, excepting that it does not appear to extend to the quadratum. It might be questioned whether this bone is not really the proötic. The element below and anterior to it (fig. 5, Pro) is emarginated for the exit of the fifth nerve (V); and though I cannot find its inferior borders, and the portion behind the above foramen is narrow, it appears to me to answer more nearly to the proötic of

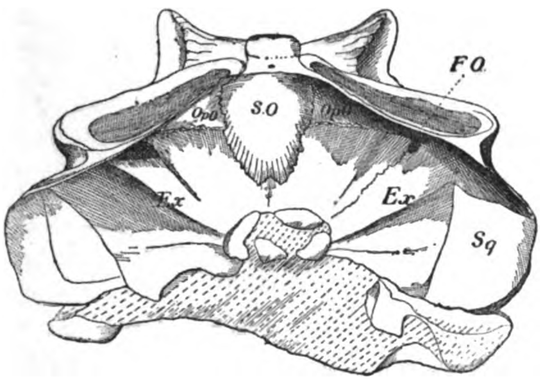


Fig. 6. — (Cranium from behind.)

Lacertilia than to an alisphenoid, which it would otherwise be. This is the more probable, in view of the fact that the supposed epiotic has its counterpart in Sphenodon, in which case this must be proötic.

The fenestra ovale (fig. 6, FO) is not readily discovered, but appears to be represented by a rather small oval foramen-like emargination of the exoccipital. It is situated just within the quadrate plate of the squamosal, and beneath the zygomatic process. I find no stapes. If it existed, it extended outwards beneath the overhanging margin of the squamosal, on the plane of the superior margin of the os quadratum.

Turning now to those portions of the cranium which are better known in allied species, I find the exoccipitals undivided, as did Owen in Pt. declivis, and Huxley in Pt. murrayi. I do not even find a median suture separating that of the right side from the left. Each presents a strong rib extending to opposite the zygomatic arch. The inferior portion is a subtriangular plate, continuous superiorly with the rib just mentioned. It is also raised

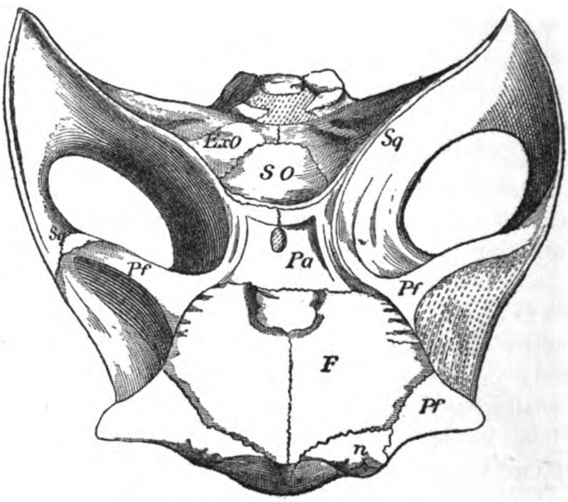


Fig. 7.—(Cranium from above.)
Lystrosaurus frontosus. (Lettering as in figs. 1 and 2.)

on the median line, and the inferior outline is concave and directed downwards. The supraoccipital is vertically ovate, and separated from the parietals by squamosal sutures. It does not reach inferiorly to the occipital foramen.

The parietals viewed from above form together a subquadrate plate, with the angles much prolonged; the anterior broadly to the postfrontals; the posterior as laminæ between the squamosals and opisthotics forming the parieto-squamosal arch. They embrace a rather large fontanelle, from which the median suture is distinct posteriorly, but invisible anteriorly.

The frontals are marked posteriorly by a large tuberosity, which bounds inwardly a concave surface on each side between it and the raised margins of the orbits. These margins are continued poste-

riorly. This raised margin is turned inwards above the postfrontals, giving the orbits a slight postero-superior notch, which is much less developed than in Pt. declivis, according to Owen's description. It is slightly rugose in consequence of transverse grooves. They are prolonged into the prefrontal tuberosities, which are very large, more developed than in any other species, resembling rudimental horns. They present a sharp edge outwardly, as the front margin of the orbits and the superior and anterior planes are at right angles to each other. The middle line of the front, descending more gradually, causes the angle between it and the premaxillary to be rather more open.

The premaxillary region is remarkably contracted; and its length from the front is about equal to the distance between the prefrontal horns, producing a T-shaped outline. On the middle line it presents a high laminar keel, which separates two parallel sulci. These extend to the end of the muzzle, and are bounded externally by a strong longitudinal angle. The external face of the maxillary is occupied by a wider longitudinal concavity parallel to the last. The posterior angle of the bone flares out behind it. The posterior (superior) "spine" of the premaxillary extends far between the nasals, and nearly to the anterior prolongation of the frontal.

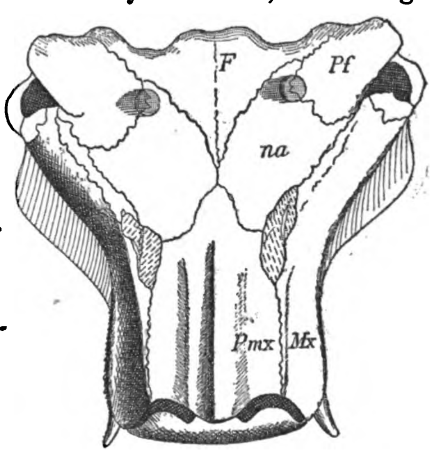


Fig. 8. — Lystrosaurus frontosus.
(Lettering as in fig. 1.)

The nasals are prominent, each presenting a low boss forwards, which enclose a concavity on each side with the tuberosity of the premaxillary spine. They overhang the nares superiorly.

The lachrymal is a small bone intercalated between the prefrontal and the maxillary. In front of and below it, a larger bone extends to the nostril, constituting the principal part of its posterior boundary. This bone is described by Owen in the Pt. latifrons. Its homologies are not determined.

The alveolar margin of the upper jaw is undulating, presenting a short median beak-like prominence, then a concavity, and poste-

riorly a convexity to the tusk. The edge of the mandibular arch is correlated between these cutting edges, but its extremity is three-lobed. These lobes correspond to three grooves within the premaxillary portion of the edge of the jaw, which are separated by two ridges. The section of the tusks is cylindric, and where broken, at the alveolar margin, the pulp cavity is minute.

The malar bone is small, and of a subtriangular form, one apex being posterior. The antero-superior angle extends to the lachrymal, thus excluding the maxillary from the circumference of the orbit.

The dentary bone extends far posteriorly, and forms the greater part of the circumference of a longitudinal foramen, which pierces the middle of the ramus. The angular is prolonged into a keel-like plate below, which is truncate behind, and rises gradually anteriorly. Its margin, which articulates with the articular, is cut out by a deep foramen.

The angular and articular bones are both horizontal. The coronoid appears to be broken off, interior, or wanting. The angular extends to the symphysis.*

The palatal surface is not exposed.

Affinities of the Anomodontia.

The attachment of the os quadratum, with the Mammalian type of rib articulation, and the elongate sacrum, induced me to regard the Anomodontia as a subgroup of the Archosauria. The absence of the quadratojugal arch, usual in the latter order, and the lack of information respecting the mode of attachment of the os quadratum, rendered it probable that the group was aberrant, or even not properly referable to it. The extension of the exoccipital bones, so as to close the parieto-squamosal arch, is found among Lacertilia in the Stenodactylus guttatus, and a very few other species; but its extension to the quadratum below the proximal articulation does not occur.

The immovable articulation of the quadratum throughout its length to the squamosal, and by its whole inner margin (as I suspect, but cannot see without too much injury to the specimen) to the exoccipital, removes the Anomodontia from the Lacertilia, and associates them with the Archosauria, in accordance with the indications furnished by the ribs, sacrum, etc. The withdrawal of

* See Trans. Amer. Philos. Soc., 1869, pp. 27, 33.

the proötics and opisthotics from its support constitutes a step towards the liberation of the quadratum, and places it nearest the Lacertilia, in the order. This indication is confirmed by the simple premaxillary bone, and the lack of quadratojugal arch.

Among Lacertilia, the Chamæleontidæ make the nearest approach, though a remote one. This is seen in the posterior prolongation of the dentary bone, and the often rudimental dentition.

The nearest approach outside the Archosauria is to the Rhynchocephalia, as represented by the existing genus, Sphenodon.* Here the canine teeth begin to show an increased development, and the other teeth to become obsolete or confluent. The nearest approach to the great development of the squamosal in Anomodontia is seen in this genus, and they both possess an ossified septum orbitorum. In both, the posterior extremity of the pterygoid is much expanded, and supports a columella.

In summing up, the following significance may be attached to the above characters. From this it will be seen that the Anomodontia present a remarkable combination, and well deserve the appellation of a "generalized type." Characters of Crocodilia are: 1. Presphenoid keel; 2. Expanse of pterygoid to unite with it; 3. Foramen of the mandible; 4. Reduction of zygomatic bone. Testudinata: 1. Edentulous jaws; 2. Coössified mandibular rami, with foramen. Rhynchocephalia: 1. Largely developed squamosal; 2. Osseous interorbital septum; 3. Distinct ? epiotic; 4. Biconcave vertebræ; 5. Columella; 6. Foramen parietale; — the last two belonging also to the Lacertilia, which have further in common with Lystrosaurus: 1. Absence of quadratojugal arch; 2. Simple premaxillary bone (mostly).

Ichthyopterygia: 1. Parietal and quadrate branches of squamosal; 2. Sessile suspensorium of quadrate; 3. Posterior flat opisthotic.

Dinosauria: 1. Elongate sacrum; 2. Ribs continued to sacrum; 3. Capitular and tubercular attachment for ribs on neural arch and centrum, respectively.

From the preceding evidence, it is clear that the Anomodontia constitute the most generalized order of Reptilia of which we have any knowledge; and occupying, as it does, almost the first or oldest place in geologic time among the Reptilia, — *i. e.*, in the Triassic period, — it justifies the statement that the peculiarly older

* See Günther, Trans. Royal Society, 1867, Pt. II., p. 1.

forms of life are the more generalized in structure than the later, and that this generalization is increasingly evident the further back we carry our inquiries.

4. *On the Homologies of the Opisthotic Bone.*

This element, distinguished by Huxley from those which compose with it the "temporal bone" of anthropotomists, has been called "mastoid" by Owen, and "external occipital" and "mastoid" by Cuvier.

Its position is exterior to the exoccipital, posterior to the proötic, and beneath and behind the squamosal.

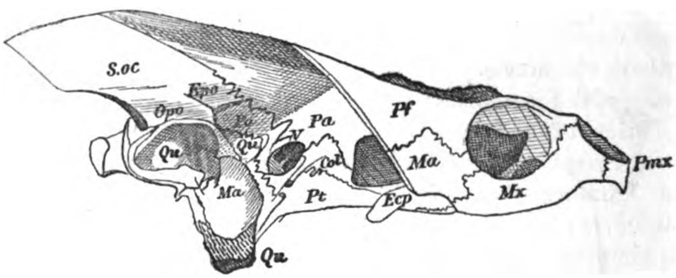


Fig. 9. — Chelydra serpentina; cranium, with squamosal and postorbital bones removed. Epo, Epiotic; Pro, or Po, Proötic. Ma, Meatus Auditorius. Ecp, Ectopterygoid. V, Foramen ovale.

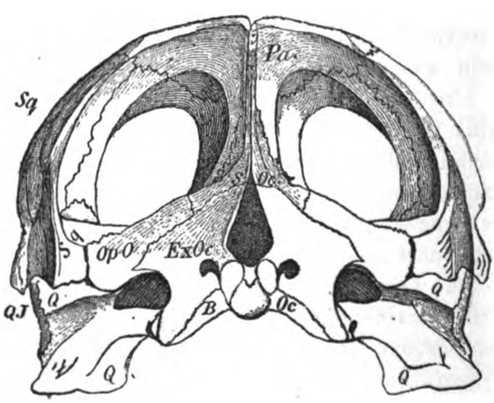


Fig. 10. — Chelone midas; cranium from behind. (Lettering as in fig. 2.)

In Mammalia it is confluent with the elements mentioned, remaining distinct from the exoccipital, and forming part of the "mastoid and petrous portions of the temporal." (Huxley.)

In Aves it is early confluent with the exoccipital. (Parker.)

In Reptilia it is distinct in all the orders except the Crocodilia, where it is confluent with the exoccipital. (Fig. 11, Exo.)

This group resembles the higher vertebrates in the close union of the quadratum with the proötic and other cranial bones; and we pursue the line of extreme Reptilian divergence in following the gradual removal of the quadrate from the cranial walls, on the

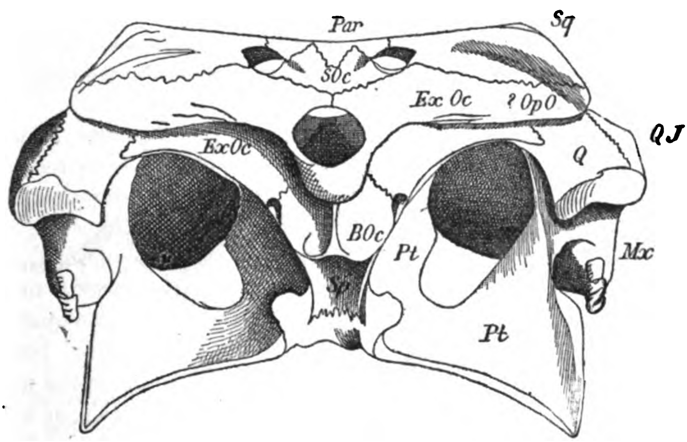


Fig 11. — Alligator mississippiensis; cranium from behind.

extremity of a suspending cylinder, which reaches its highest expression in the Ophidia. First in this succession comes the separation of the opisthotic.

We have already seen its position in Ichthyopterygia (fig. 1, Opo) where it is peculiar in separation from the supraoccipital and connection with the basioccipital. We have also seen an element in the Anomodontia identified with it (fig. 6, Opo) which differs in its connections, by being attached to the supraoccipital and exoccipital only.

Passing to the Testudinata, the element maintains the same connections, with the addition of that with (fig. 10, Opo) the proötic anteriorly, and is extended externally over the proximal extremity of the quadratum, a connection not observed in the types just described.

If we now turn to the Rhynchocephalia, as represented by Sphenodon,* we find the exoccipital greatly prolonged laterally, and carrying with it the opisthotic. It is carried apparently beyond any connection with the proötic (alisphenoid of Günther), but is less distant from the supraoccipital, or rather the epiotic (paroccipital, Günther), which is here, according to Günther, not entirely separated from the supraoccipital, as in the Testudinata, though more so than in the latter. Its superior and anterior extent is remarkable in this genus, forming a connection with the postorbital above and the malar below, peculiarities not noticed in any other reptile. Superiorly it rises into the parieto-quadrate arch, which it forms with the squamosal, the parietal not entering it; another peculiarity, the only parallel to which is to be found in the Anomodontia, where this arch is however depressed into close contact with the occipital segment of the skull.

The type exhibited by the Lacertilia is intermediate between that of the last and that of the Tortoises, and serves to reconcile them. Here, also, the opisthotic is carried beyond connection with the other otic elements. In Iguana it contributes largely to the formation of the parieto-quadrate arch, but with the parietal instead of the squamosal, and on the under instead of the upper side, as in the genus Sphenodon. (See figs. 13, 14, OpO.) In Chamæleo it is a mere wedge articulating with the proximal end of the quadratum, and not entering into the parieto-quadrate arch.

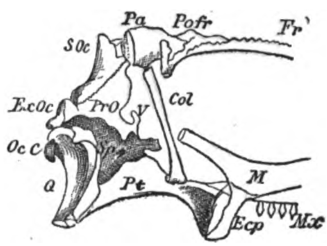


Fig. 12.—Iguana tuberculata; posterior arches removed.

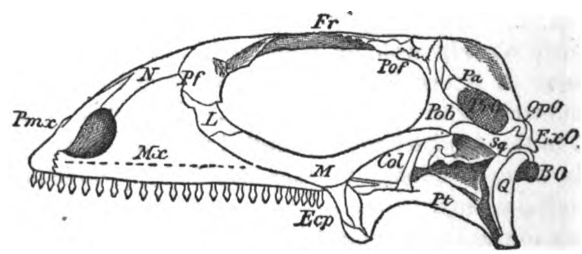


Fig. 13.—Iguana tuberculata; lateral view, with arches.

* I rely on the figures and descriptions of Günther, in his paper on the Anatomy of Hatteria (Philos. Trans., London, 1867).

In the Pythonomorpha its character as "suspensorium" of the quadrate is still more pronounced; yet, though it forms part of a cylindric bar extended transversely from the brain-case, it maintains a sutural union with the proötic (see fig. 15, OpO), and to a slight degree in Clidastes, with the supraoccipital, or ? epiotic portion of it. If there be any parieto-quadrate arch (a doubtful point), it probably enters into it posteriorly.

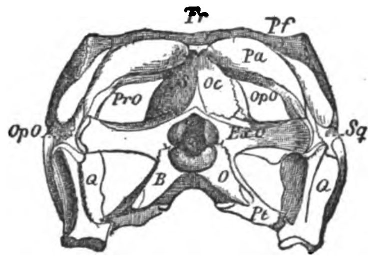


Fig. 14. — Iguana, from behind.

In the Ophidia it exhibits an important range of variation. I have not been able to find it in Typhlops.* In Cylindrophis it is

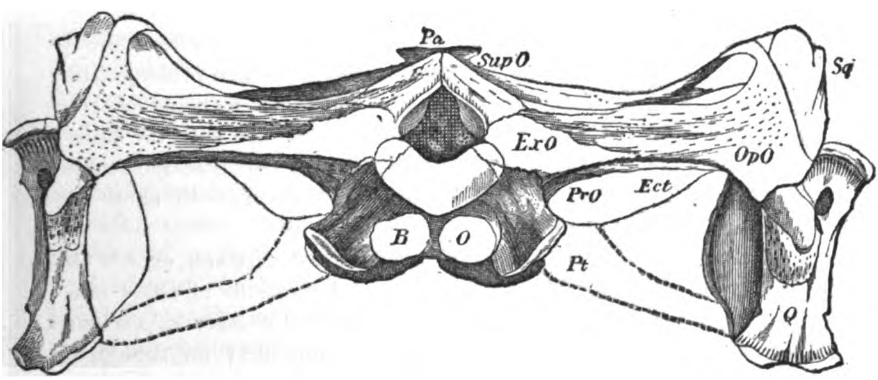


Fig. 15. — Clidastes propython, Cope; cranium from behind.

enclosed as usual between the exoccipital behind, the proötic anteriorly and inferiorly, the parietal above, and a small area enclosed between the latter and the exoccipital, which is either the extremity of the supraoccipital or a distinct element, perhaps epiotic. (See fig. 16: BO, Basioccipi-

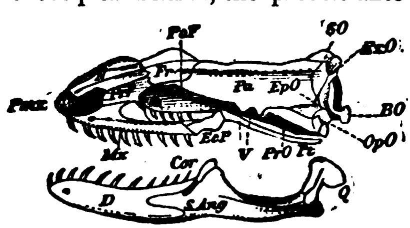


Fig. 16. — Cylindrophis rufa.

* In an osteological system of the scaled Reptilia, published in "Proceedings of the Academy of Natural Science," Phila., 1864, p. 224, an error occurs, in

tal; ExO, Exoccipital; SO, Supraoccipital; OpO, Opisthotic; PrO, Proötic; EpO, Epiotic; Fr, Frontal; PoF, Postfrontal; Prf, Prefrontal; N, Nasal; Pmx, Premaxillary; Mx, Maxillary; Ecp, Ectopterygoid; Q, Quadrate; Art, Articular; Cor, Coronoid; D, Dentary; V, Foramen ovale.) The obtuse extremities of the opisthotic and exoccipital support together the os quadratum.

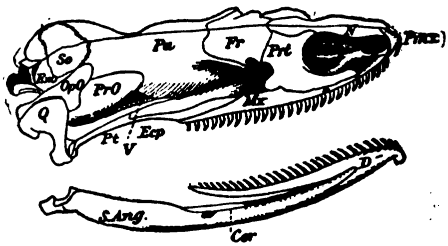


Fig. 17. — Xenopeltis unicolor (Siam).

In the rather more specialized Xenopeltis, the opisthotic is no longer intercalated between the proötic and exoccipital, but lies over the common suture of the two, united by a squamosal suture. This important change transfers us from the Tortricina to the Asinea, as defined by Müller. (See fig. 17, OpO.) Throughout the latter suborder it only increases in length, which prolongation reaches its highest expression in the venomous serpents of the suborder Solenoglypha. It has been homologized with the squamosal in these groups by Huxley (Elements of Comparative Anatomy), but incorrectly, as I believe, and attempt to show in considering that bone.

Among the Batrachia this element is not distinct, except in Necturus. (See fig. 22, posterior view of cranium of Rana mugiens.) I have failed to find it entirely distinct in larvæ of various ages of Amblystoma, Spelerpes, and Gyrinophilus; for though a suture from the fenestra ovale to the foramen condyloideum sepa-

which I say in the definition of the Scolecophidia, p. 230, "no prefrontal." This should have read "no opisthotic." The prefrontal is largely developed in Typhlops, while the maxillary is much reduced, and concealed on the inferior face of the cranium alongside the vomers. In the portion devoted to the Lacertilia, p. 225, several expressions occur which need explanation, owing to the fact that the homologies of some of the elements were not at that time worked out. Thus the "temporal bone" is the proötic, and the "mastoid" is the opisthotic. I must also correct the nomenclature of the elements of the mandible here, and in Clidastes, as published in Trans. Amer. Philos. Soc., 1870, pp. 214–16. Angular should read *articular*, articular should read *surangular*, and subarticular should read *angular*. In cut 51, figs. 3 and 5 belong to one bone, which is the *angular*.

rates it inferiorly from the exoccipital in several species, the superior suture is wanting or invisible.

The opisthotic is known to be distinct in osseous Ganoids and Teleostei.

5. *On the Homologies of the Squamosal Bone.*

As this bone derives its name from its Mammalian representative, it will be well to trace it from that class. It may be defined as the bone which occupies the space between the proötic in front, the opisthotic behind, and the parietal above, which subtends the auricular bones or meatus superiorly, and forms the posterior extremity of the zygomatic arch.

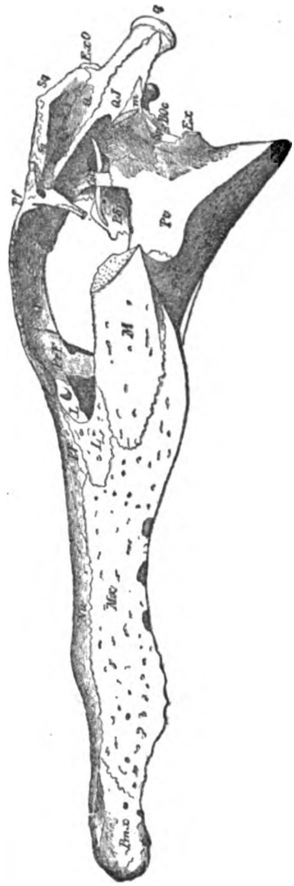


Fig. 18.—Alligator mississippiensis; cranium, with arches removed, and a pointer passed behind the columella.

In the Birds the zygomatic arch does not exist, and the malleus is produced from beneath it, as the os quadratum, for the support of the mandible (Parker).* Here then it first assumes the position of the external shield of the quadrate, which it continues to hold throughout the series of Vertebrata below this point.

In tracing its homologies in the Reptilia, we commence with those in which the quadrate is most nearly sessile on the cranium, as in the Birds, and proceed towards those in which the latter is supported at the extremity of a prolongation of the posterior elements of the cranium, or a "suspensorium."

I may add here that the former relation of the quadrate, being most similar to that found in both the Birds and the Stegocephalous, and other tailed Batrachia, is the most generalized;

* On the Development of the Skull in the Ostrich Tribe (Philos. Trans., London, 1865, p. 118).

while the suspensorial type is the most divergent from other Vertebrata, and most specialized. Hence the successional relation of the orders of Reptilia is to be estimated by reference to their degree of approximation to either of these extremes, as will be considered further on.

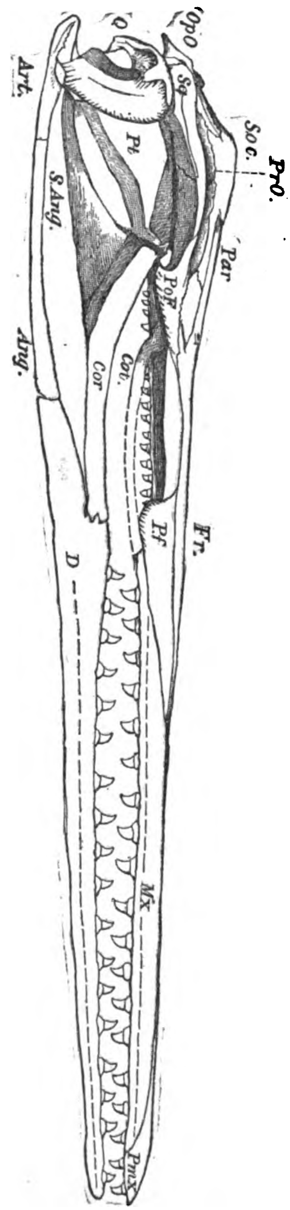


Fig. 19. — Clidastes propython; profile of cranium, with arches.

If we seek for that element, in the Crocodilia, which fulfils the requisites of the squamosal as above defined, we find it on the posterior superior lateral angle of the cranium. (See fig. 18, Sq.) It sends forwards an anterior process, which completes the zygomatic arch posteriorly, and with the postfrontal (Pf) bone encloses the temporal fossa. As its union with the quadratum is on the under side of the latter, it is concealed from view in fig. 18, chiefly by the superior prolongation of the quadratojugal (QJ).

In the Testudinata, the quadrate being removed from the cranial walls, the position of the squamosal is more exterior. (Fig. 10, Sq.) In Chelone, it sends an extension upwards to the parietal, forming the parieto-quadrate arch, which is not observed in most other Testudinata. The enclosed space is much more expanded than in Crocodilia (fig. 11), where it is in fact reduced to a foramen above each supraoccipital.

The position of the squamosal in the Pythonomorpha is very similar to that seen in the last order, but it is further removed from the cranial walls (fig. 19, Sq), in consequence of the greater length of the suspensorium.

In the Lacertilia it is carried far from the cranial walls by the increased length of the exoccipital, from

which, as in the Testudinata, the opisthotic separates it. (See figs. 13, 14, Sq.) In most of the order it has no contact with the parietal, the parieto-quadrate arch being supported below by the opisthotic, as above pointed out. But in the Rhiptoglossa (Chamæleo) the squamosal sends a long process upwards, which meets a prolongation of the parietal, which is however single and median, and not bifurcate as is usual. The opisthotic does not rise with it. In the Ophiosauri (Amphisbænia), it appears to be wanting, as Müller has already indicated; and there are various stages of reduction to be observed among the Typhlophthalm lizards which approach them.* In the Aniellidæ it is wanting, while it exists in a rudimental state in the Acontiadidæ. (Fig. 20, Ramus mandibuli, quadrate, and suspensorium of Acontias meleagris, Sq.)

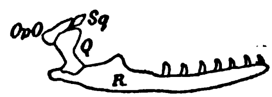


Fig. 20.—Acontias meleagris, S. Africa; mandible and suspensorium.

In the Ophidia the squamosal is obviously wanting. This is proven in two ways: first, by the serial homology of the opisthotic, from Lacertilia through Pythonomorpha (fig. 15), or Tortricina (fig. 16), with the single suspensorium of the quadrate in typical snakes; and, second, by the successive diminution of the squamosal in the Lacertilia from the Leptoglossa through the Typhlophthalmi, where it is rudimental in Acontias (fig. 19), and wanting in Aniella, and in the succeeding group of Amphisbænia. Therefore its identification with the suspensorium in Ophidia, proposed by Huxley, must be abandoned.†

Returning to the earlier types of Reptilia, we may recall the features of the squamosal already ascribed to the Ichthyopterygia and Anomodontia. The first peculiar feature, the anterior prolongation on each side of the cranium, on the inside of the temporal fossa, separating widely the supraoccipital and parietal, was shown to exist also in the Rhynchocephalia. The question of the real pertinence of this prolongation to the squamosal may be raised, as it is remote from the position of that bone in most of the Lacertilia, and in some specimens of Ichthyosaurus is separated by suture from it. Its relations in Chamæleo throw much light on the point, and render it highly probable that the cranial prolongation in the three groups just mentioned is really continuous with it. As pointed out above, the squamosal in Chamæleo extends inwards to the parietal, forming the greater part of the parieto-quadrate

* See Essay on Primary Groups of Reptilia Squamata (Proceedings Academy of Natural Science, Phila., 1864, p. 230).

† See, on Pythonomorpha, Trans. Am. Philos. Soc., 1869, p. 178.

arch, as in Ichthyosaurus and Lystrosaurus, differing only in its elevation above the occipital elements as an arch, instead of being closely depressed upon them. It has been already suggested in this essay, that this portion may include the epiotic element.

The second peculiarity is observed in Sphenodon, and is quite unparalleled. This is that the opisthotic expands over the external face of the squamosal, concealing it from outside view, and occupies the greater part of the posterior face of the parieto-quadrate arch. Its position suggests at first the inquiry whether the identification of the two elements here adopted is not the reverse of the true one. The relations of the opisthotic to the exoccipital are, however, as elsewhere; while the squamosal forms the inner side of the zygomatic arch behind, and occupies in part the position seen in Lystrosaurus.

The third peculiarity already described is the posterior inferior production of the squamosal in Ichthyosaurus and Lystrosaurus. In the latter it is very remarkable, and covers the outer side of the quadrate completely.

The last feature is alluded to for the purpose of carrying the homology of the squamosal into the Batrachia. Huxley (Elements Comparative Anatomy) does not allow himself to compare any element in that class with this bone in the Reptilia, and, alluding to the "tympanique" (Cuvier) of the frog, says it is too different from the squamosal to be compared with it. If, however, he had had the cranial structure of Lystrosaurus, he could no longer have doubted, but would have homologized them at once. (Figs. 21, 23, Sq.) Dr. W. K. Parker has ventured on this step, and identified the squamosal in the Batrachia, in accordance with the present views, on embryological grounds alone.*

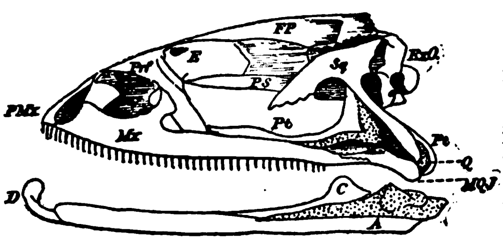


Fig. 21. — Cranium of Rana mugiens; profile.

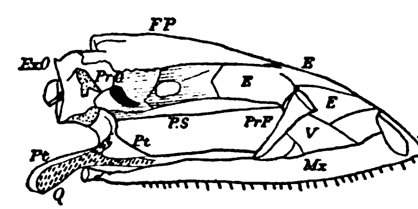


Fig. 22. — Same, with squamosal, prefrontal, and maloquadratojugal (MQ.J) removed. P.S, Parasphenoid; V, Vomer; E, Ethmoid.

* See London Philos. Trans., 1865, p. 162.

The quadratum, cartilaginous in the Anura, is osseous in the Urodela, and is obviously represented by a bone beneath the preoperculum of the Dipnoi, which, as Huxley has shown, is distinct from the latter. The preoperculum is here obviously the squamosal of Amphiuma and other Urodela (fig. 23, Sq), so that we now have determined the identity of the reptile squamosal with the preoperculum of the bony fish. And, more, it

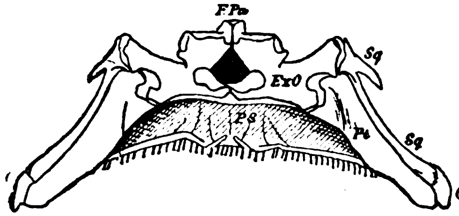


Fig. 23.

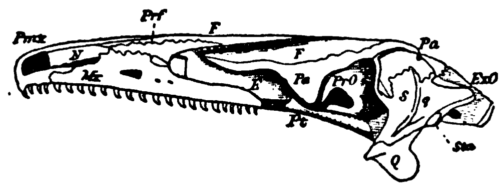


Fig. 24.—Amphiuma means (from Georgia); profile of cranium.

appears to be demonstrated that the squamosal portion of the temporal bone of the Mammal is the preoperculum of that type.*

6. *On the Homologies of the Columella.*

With regard to the character of the Reptilian columella, the following conclusions seem to be indicated by a study of the crania of Crocodilus, Lystrosaurus, Chelydra, and Iguana. There are two modes in which the parietal arch is completed laterally among Reptilia. The usual mode among Vertebrates is where an alisphenoid connects the parietal and sphenoid bones. This characterizes the Crocodilia and Pythonomorpha.† In the second mode, the peculiar bone called the columella stands pillar-like on the pterygoid, supporting the parietal (in Gecconidæ not reaching the latter). This arrangement characterizes the Lacertilia, where the alisphenoid is entirely absent. In the Ophidia and Testudinata, the parietal sends down a plate-like border or process on each side, which in the latter articulates with a flat bone, which

* The bone homologized by Huxley (Elem. Comp. Anat., figs. 69–73, Sq) with the squamosal in the Telosei must, if the above determination be correct, have another interpretation.

† The decurved margin of the parietal takes its place in the Ophidia.

is in like manner united with the pterygoid.* The latter bone is longer than deep (see fig. 9, Col), and very different from the columella of Lacertilia, though its position would render it probable that it represents that bone. The existence of the parietal or squamosal plates in Lystrosaurus, continuous with a veritable columella, which rests by a laminiform extremity on the pterygoids, confirms the position that the Chelonia, like the Lacertilia, possesses a columella.

In Lystrosaurus (fig. 5, Col), the structure is analogous to that of the Crocodilia, already described. The continuity of the inner margin of the pterygoids with the presphenoid and sphenoid is common to both orders. From a position on this part of the pterygoid, in the genus Alligator, there rises, exactly as in Lystrosaurus, an osseous style. (Fig. 18, Col.) It is in front of the foramen ovale, and is separated from the alisphenoid by a narrow foramen, which opens anteriorly. Above the latter it is coössified in adult age with the superior part of the alisphenoid, and both together meet the lateral portion of the parietal, which here descends much less than in Testudinata, forming only a ridge. I regard the short column of Alligator, above mentioned, as functionally the columella.

In the Lacertilia and Rhynchocephalia, the columella is not continuous above with any determinable element. (Fig. 12, Col.)

In the Ichthyopterygia, it is continuous above with the parietal extension of the squamosal. (Fig. 3, Col.)

It appears, therefore, that there are at least four modes of origin of the superior extremity of the columella; viz.: —

Confluent with epiotic or parietal, — Ichthyopterygia, ? Anomodontia.
Confluent with alisphenoid, — Crocodilia.
Suturally united with parietal, — Testudinata.
Approaching or touching parietal without suture, — Lacertilia, Rhynchocephalia.

The first two types cannot therefore be homologized with each other, nor the second with the third and fourth. The latter two forms of columella are probably homologous.

Having reviewed the homologies of the opisthotic, squamosal, and columellar bones, I append a table of their synonymes, with those of a few others.

* This bone is overlooked by Stannius, who says the parietal plates rest on the pterygoids.

Nomenclature adopted.	Batrachia.	Ichthyopterygia. Owen, Palæontology.	Anomodontia. Owen, Jour. Geol. Soc.	Rhynchocephalia. Günther, Sphenodon.	Testudinata. Cuvier, Oss. Foss.	Lacertilia. Cuvier, Oss. Foss.	Ophidia. Huxley, El. Comp. Anat.	Ornithosauria. Owen, Dimorphodon.
Opisthotic	Mastoid (Owen)	?	Parietal	Mastoid	Occipitaux extérieurs	Mastoïdien	Squamosal	
Squamosal	Tympanique, Cuv. Temporo-mastoïdien, Dug.	Parietal pt. Supratemporal	Mastotympanic	Parietal pt.	Mastoid	Temporal	O	
Quadrato-jugal	Tympano-malleal, Dug.	Squamosal	O	?	O	O	O	
Proötic	Rupeoptereal, Dug.	?	?	Alisphenoid	Rocher	Rocher	Proötic	
Postorbital	O	Postorbital	No. 27	Zygomatic	O	Postfrontal	O	

7. *On the Systematic Arrangement of the Reptilia.*

a. On Systematic Classification in general.

The *rationale* of systematic classification, in zoölogy at least, is a problem unsolved in the minds of many. As Agassiz has observed, it reposes in most cases on a purely empirical basis; and such are the difficulties that a resolution of its true nature presents, that some of the best naturalists have been fain to admit that it does not rest on any basis of principle of natural order, but on the convenience of the student alone. Yet I presume that even these will hardly admit their position to be true, if brought face to face with such a legitimate deduction from it as that a classification based purely on coloration or size would be as satisfactory as that they adopt. Believing that a true classification of species of organic beings based on their structure will be the expression of some of the laws according to which their creation has been conducted, as well as of some of those which govern their mutual relations in the scenes of active life, I would propose to state the principle which I imagine to lie at the basis of a system which fulfils such requirements.

In practice, so general is the coincidence of external and readily visible characters with the deeper and more significant ones, that the usual practice of arranging groups of animals in accordance with some readily observed tangible character of the former kind is generally justified by the more conclusive test of an examination of the whole structure. Yet this method fails to stand such tests sufficiently often to render it obvious that external characters are not enough for the resolution of the problem of affinity, and that they may be deceptive in cases where we little suspect it. As an example of the first, the genus Sphenodon is sufficient. In characters usually employed by naturalists for distinguishing the families of Reptilia, it is an Agamoid Lacertilian: a complete examination of its anatomy has shown that it is not even a member of the order Lacertilia. In the second case of deceptive characters, those of the corresponding genera of different homologous series may be mentioned, where the characters determining the series are rarely visible externally.

Some valuable propositions respecting classification are made by Professor Gill, in an essay on the Mammalia, read before the American Association (to be published in abstract in its volume, and in the "American Naturalist" for October, 1870). His first two prop-

ositions are: "1st, Morphology is the only safe guide to the classification of organized beings, teleological or physiological adaptation being the most unsafe guide, and conducing to the most unnatural approximations; 2d, The affinities of such organisms are only determinable by the sum of their agreements in morphological characteristics, and not by the modifications of any single organ."

The first proposition we think so self-evident, that it is surprising that there are naturalists who, in practice at least, do not consent to it. Morphology is simply the determination of what the elements of an organism are; a question which obviously lies at the root of things, and demands attention before the question of the uses of said parts can be considered.*

The discussion of the second proposition involves the main question. I conceive it to be a very good expression of the views of many naturalists, yet, in my own, it does not go far enough; nor is the second clause, that "affinities are determinable" "not by the modifications of any single organ," one with which I can agree. The same objection therefore applies to the corollary following, that "the adoption of such principles compels us to reject such systems as are based solely on modifications of the brain, those of the placenta, and those of the organs of progression," etc. In other words, agreeing with the first part of Prop. 2, that "affinities" "are only determinable by the sum of their agreements in morphological characteristics," we do not regard the remainder of the proposition and its corollary as necessary consequences of it.

If we analyze the "sum of the agreements" of given groups, we cannot affirm that all of those separate characters which constitute that sum have been always, in past time, coëxistent. In fact, we know that they have not been so, and that the differences of groups consist in the abstraction of single characters from, or addition of single characters to, this "sum." Hence the history of this "sum" is the history of the single characters which compose it, and each one of them has a special value of its own, which cannot be sunk in a state of association. If this be true, systematic zoölogy stands upon what some naturalists are pleased to call a purely "technical" basis, as opposed to what they term a "natural" one. And this is distinctly our position. Every structural feature possesses some systematic value, and when our knowledge extends over a greater number of forms than the

* See Proceedings Academy of Natural Science, Phila., 1863, p. 50; Natural History Review, 1865, p. 98, etc., where this view is expressed.

system at present includes, the definitions of our groups will rest upon single characters only, and the history of the origin of those characters will be the history of the origin of the groups.

It is the proper discrimination of the relative values of these single characters which in our estimation determines the "naturalness" of a system; and the principle on which such discrimination reposes is the key to that perplexing question which often renders the conclusions of naturalists so different in appearance, while the objects of their investigations are the same. But by misusing "technical" or single characters — that is, by misinterpreting their values — the most erroneous approximations may be made, and systems constructed which well deserve the term "artificial" applied to them by those who, in their search for the "natural" system, are opposed to the use of "technical" characters. Perhaps the best known example of this misuse is to be found in the Linnæan system of botany, where the value of the numbers of stamens and pistils in determining affinity was placed much too high. Though this system has been utterly abandoned, yet Linnæus's characters are still of great importance in a lower grade of relations.

As the number of primary groups of the animal kingdom is but small, I will commence with the principle on which all subordinate divisions may be distinguished, and their value ascertained.

I. Given primary divisions, and given that such divisions present in some members greater resemblance (or unity of minor characters) to members of other primary divisions, and in other members especial diversity from the same, — the primary subdivisions of said first divisions are those which express the successional degrees of resemblance to or difference from the other divisions of first rank.

II. Given primary subdivisions, their subdivisions of first rank are estimated, as in Prop. I., by reference to the characters presented by their extremes of likeness to or diversity from the members of the other primary subdivisions. The value of characters of the groups contained in each of last grades mentioned to be determined by the same test.

For primary divisions, in Prop. I., might be read *class;* for primary subdivision, *order;* and for subgroup of the latter, *family.* The same principle applies to genera, which is expressed in Prop. VI. of a series designed to render clear the basis of the theory of evolution, published in a "Monograph of the Cyprinidæ of Penn-

sylvania." * The I., II., and III. propositions are prefixed as preliminary: —

I. That genera form series indicated by successional differences of structural character, so that one extreme of such series is very different from the other, by the regular addition or subtraction of characters, step by step.

II. That one extreme of such series is a more generalized type, nearly approaching in characters the corresponding extreme of other series.

III. That the other extreme of such series is excessively modified and specialized, and so diverging from all other forms as to admit of no type of form beyond it.

VI. That therefore the differences between genera of the same natural series are only in those characters which characterize the extreme of that series.

For the highest groups in the animal kingdom we must accept the definition of Cuvier, Von Baer, and Agassiz, for the present, that they are primary, because they represent different primary plans of structure. For the lowest grade of groups (genera) the definition above given (Prop. VI.) will be found to represent groups to which the definition given by Agassiz † will also apply; viz., that "their special distinction (*i. e.*, of genera) rests upon the ultimate details of their structure." I believe that the definitions given by Agassiz to the three intervening grades of divisions — viz., of families, orders, and classes — are far nearer a representation of nature than any other ever given. They are as follows: —

Classes are defined "by the manner in which the plan of the branch is executed; *Orders*, by the degrees of complication of that class-structure; *Families*, by their form as determined by structure." Natural science is under great obligations to Professor Agassiz in this, as in other points.

These definitions are, however, better perceived after the groups are constituted, but in practice are not sufficiently exact to serve as the crucial test in the cases which may arise. The simple method indicated in our propositions above will, it appears to us, serve to solve many of the more difficult questions which arise during the attempt to state the true relations of organic beings.

We may now apply these principles to the groups of the class

* Trans. Am. Philos. Soc., 1866, p. 397.

† Contrib. Nat. Hist. U. S., i. pp. 168, 170.

Reptilia, not only as an illustration of their meaning, but of their use.

β. On the System of Reptilia.

The points of resemblance to the other classes of Vertebrata presented by the Reptilia are, of course, to those below them and those above them. Relationships to the class Batrachia are as yet doubtful, unless indeed the remarkable relations of the squamosal and quadrate in Anomodontia have such a significance. The extremities of the genus Ichthyosaurus present a remarkable structure not seen elsewhere in the class, nor in the classes above it; viz., in lacking all differentiation between the elements external to the proximal element,—the humerus and femur. So far as form is concerned, the ulna and radius, tibia and fibula, tarsus carpus, metacarpus, metatarsus, and phalanges, are identical. This type is only found below the Reptilia, approximately among Crossopterygian fishes and Elasmobranchi; and it is to the latter class that we must appeal, says Gegenbaur, for an explanation of their structure. No other resemblance of real importance has been observed to exist between the two groups.

The extension downwards of the squamosal over the quadrate region constitutes a point of remote resemblance to the Fishes. The ? continuation of the ? frontals to the premaxillaries in Ichthyosaurus is seen in the lower tailed Batrachia.

Resemblances to the classes above the Reptilia are seen in the groups Crocodilia, Dicynodontia, Ornithosauria, and Dinosauria. In the first, the presence of a vermis in the cerebellum, and quadripartite heart are points of equal affinity to the Mammalia and Aves. In the three others, the double-headed ribs, with capitular articulation on the centra of the vertebræ, and generally elongate or complex sacrum, are points of resemblance both to Mammalia and Birds. In the Dicynodontia, other resemblances to either class are wanting, but the case is different in the other orders. The pelvis and hind limbs of the Dinosauria are especially bird-like; while, according to Seeley, the Ornithochiræ had epipubic or marsupial bones as in Mammalia, a brain with infero-lateral optic lobes as in Aves, and even confluent metatarsi as in the same class. In fact, it seems quite evident that Seeley is right in referring that group to the Birds; but this does not necessarily remove the true Pterodactyles from the Reptilia. These have distinct tarsals and metatarsals, though their epipubic (marsupial) bones and other characters ally them most closely to the Ornithochiræ.

Serial divergence from these lower and higher orders to an extreme of special peculiarity, such as is mentioned in Prop. III. above, has been alluded to in the discussion of the homologies of the opisthotic and squamosal bones. This is seen in the successive prolongation of the elements on the sides of the posterior region of the cranium into a "suspensorium," and the successive liberation of the quadrate bone from several sutural articulations, to a condition as a mobile fulcrum for the mandible. This succession is seen first in the Rhynchocephalia, where the suspensorium is produced, but the quadrate fixed; the Testudinata, where the quadrate is freed from a quadratojugal bone; in the Lacertilia, where the quadrate is movable, but the opisthotic not produced; in the Pythonomorpha, where the opisthotic is produced as suspensorium; the extreme being reached in the Ophidia, where the suspensorium itself becomes movable, and with it the elements which usually form the solid surface of the palate.

This series then, it is evident, is like that of the Teleostei, among the lower Vertebrata, a special divergence from the main line of succession to the higher classes. The reptiles which retain and increase the close contact of the quadrate bone with the periotic elements are evidently those which conduct us to the Mammalia. The highest group in this succession is the Crocodilia. Those which consolidate the periotic elements, but retain the partial freedom of the quadrate, on the other hand, lead to the Avine class. These are the Ornithosauria, and perhaps, when we come to know the cranium, the Dinosauria. At least this may be predicated, if the structure of the foot and ear bones are correlated in this group as they are elsewhere.

The primary importance of this series is confirmed by the correlation with it of the serial modification of the modes of attachment of the ribs. These differences were first used in systematic work by Owen,* and later more fully by Huxley.† The latter subdivides the Reptilia in accordance with it alone, and, while pointing out important affinities thereby, fails to recognize others from his neglect of the modifications of the quadrate and supporting bones.

In the most generalized form (represented by Ichthyosaurus), the capitular and tubercular articular surfaces are near together, but distinct, and situate on the sides of the vertebral centra.

* Palæontology. † Jour. Geol. Society, London, 1870.

From this point two lines of modification can be traced. The one, coinciding with that in which the quadrate and suspensorial bones are received into closer cranial articulation, is characterized by the wider separation of the two surfaces. The inferior becomes marginal and sessile, remaining on the centrum; the superior rises, and on the dorsal region is supported on an elongate basis from the sides of the neural arch. Thus, in this point also, this series tends towards the Aves and Mammalia. The second, or special series, in correspondence with the liberation of the quadrate, etc., sees a fusion of the two articular surfaces, and their usual retention on the centrum. In one group (Sauropterygia) this fused basis rises to the top of the neural arch in the dorsal region: on the cervical region they are distinct.

In the Crocodilia, the capitular articulation does not rise to meet the tubercular in front of the posterior dorsal region; and they are united and rise from the neural arch on the lumbar region. These two orders are otherwise allied, and form a point of connection between the groups defined by the characters of the rib articulations.

In the Testudinata, the ribs are single headed as in this series, but the convexity is sometimes in contact with the transverse expansion of the neural spine. There appears, however, to be no true articulation here, nor any diapophysis.* The space between the vertebral expansion and the tubercular region of the rib is filled by a later and distinct ossification. The capitular articular facets are sessile, and at the point of contact of two centra. The majority of this order present a special peculiarity in the expansion of the ribs into an osseous upper shield: a similar expansion of abdominal elements (perhaps abdominal ribs), with the clavicles† and mesosternum (interclavicle, Parker), forms an inferior shield. As these characters are not developed in Sphargididæ, they need not be necessarily regarded as ordinal.

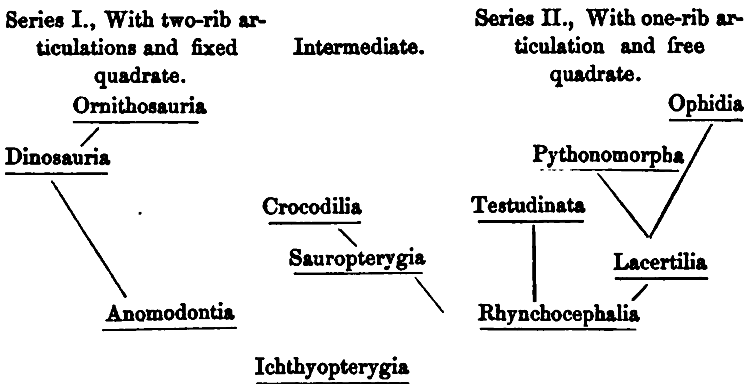
A similar character is to be found in the Pythonomorpha and Sauropterygia, whose fore limbs are specialized into swimming organs or paddles. Since we see this last modification of the truly differentiated limb to be subordinated to the characters of the order in the Testudinata (*e. g.*, in Cheloniidæ and Sphar-

* In a young *Testudo mauritanica* the proximal extremities of the ribs are decurved to their capitular articular facets, without touching the expansion of the neural spine (vertebral bones of carapace), and without sending tubercle or process to meet them.

† See Parker on the shoulder girdle.

gididæ), I do not regard it as necessarily of ordinal value, but subordinate to characters already mentioned, of the posterior regions of the cranium, the tarsus, pelvis, etc. The forms of the articular extremities of the vertebræ have also a subordinate value.

The affinities of the Orders are most easily expressed in the following outline scheme: —



A tabular arrangement destroys expression of more than one line of affinities, but is most convenient for presentation of diagnoses. The above-named groups possess different degrees of relationship to each other, and have been combined into groups by authors, which are supposed to represent natural divisions. This presents some difficulties as yet, on account of our ignorance of the structure in certain orders. They may, however, be provisionally placed as follows: —

A. Extremities beyond proximal segment not differentiated as to form.

I. Tubercular and capitular articulations for ribs distinct, on centra. Os quadratum immovably articulated to squamosal, etc. No sacrum. ICHTHYOPTERYGIA. Including one order, *Ichthyopterygia*.

B. Extremities differentiated.

II. Tubercular and capitular surfaces united. Os quadratum articulated with squamosal and opisthotic by ginglymus. Sacrum very small. STREPTOSTYLICA, with the orders *Lacertilia*, *Pythonomorpha*, and *Ophidia*.

III. Tubercular and capitular surfaces united. Os quadratum articulated with squamosal, opisthotic, etc., by suture. Sacrum small. SYNAPTOSAURIA, with the orders *Rhynchocephalia*, *Testudinata*, and *Sauropterygia*.

IV. Tubercular and capitular surfaces separated; former on diapophysis, latter on centrum. Os quadratum articulated by suture with its suspensorium. Sacrum generally of several vertebræ. ARCHOSAURIA; orders, — *Anomodontia*, *Dinosauria*, *Crocodilia*, and *Ornithosauria*.

CATALOGUE OF THE FAMILIES OF THE REPTILIA.*

I. ORNITHOSAURIA.

Bonaparte, Fitzinger, Seeley; *Pterosauria*, Owen.
Dimorphodontidæ; Dimorphodontæ, Seeley, l. c.
Pterodactylidæ; Rhamphorhynchæ et Pterodactylæ, Seeley, l. c.

II. DINOSAURIA.

Owen, Cope, Seeley; *Pachypodes*, Meyer. *Ornithoscelida;* Huxley.

1. Symphypoda.

Cope; *Compsognatha*, Huxley.
Compsognathidæ; Compsognathus, Wagner.
Ornithotarsidæ; Ornithotarsus, Cope.

2. Goniopoda.

Cope; *Harpagmosauria*, Haeckel.
Megalosauridæ; Huxley (part). Cope, Trans. Am. Philos. Soc., 1869, p. 99.
Teratosauridæ; Teratosaurus, Plateosaurus, Meyer, etc. Cope, Trans. Am. Philos. Soc., 1869, p. 90.

3. Orthopoda.

Cope; *Therosauria*, Haeckel.
Scelidosauridæ; Cope, Trans. Am. Philos. Soc., 1869, p. 91; Huxley, Jour. Geol. Soc., London, 1870, p.
Iguanodontidæ; Cope, l. c.; Do. (in part), Huxley, l. c.
Hadrosauridæ; Cope, l. c.; Iguanodontidæ, Huxley (part).

III. CROCODILIA.

Crocodilia et *Thecodontia* (part), Owen, 1841.

1. Amphicœlia.

Belodontidæ; Thecodontia, Owen (part). Cope, Trans. Am. Philos. Soc., 1869, p. 32.
Teleosauridæ.

* The extinct groups and synonymes are indicated by italics.

2. Procœlia.

Thoracosauridæ; Thoracosaurus, Leidy, Cope.
Gavialidæ; Gavialidæ, Gray; + Holops Thecachampsa, Cope, etc.
Crocodilidæ; Crocodilidæ + Alligatoridæ, Gray.

IV. SAUROPTERYGIA.

Owen.
? *Placodontidæ;* Placodus, etc.
Plesiosauridæ; Nothosaurus, Pistosaurus, Plesiosaurus, Pliosaurus, etc.
Elasmosauridæ; Elasmosaurus, Cimoliasaurus, etc.

V. ANOMODONTIA.

Owen.
Dicynodontidæ; Owen, Palæontology.
Oudenodontidæ; *Cryptodontia*, Owen, Palæontology.

VI. ICHTHYOPTERYGIA.

Ichthyosauridæ.

VII. RHYNCHOCEPHALIA.

Protorosauridæ; Protorosaurus, Meyer (elongate sacrum).
Sphenodontidæ; Hatteriidæ, Cope (Proceed. Acad. of Nat. Sci., Phila., 1864).
Rhynchosauridæ; Rhynchosaurus, Owen.

VIII. TESTUDINATA.

1. Athecæ.

Sphargididæ; Gray, Annals of Philosophy, 1825; Bell, Fitzinger, Agassiz.

2. Cryptodira.

Cheloniidæ; Gray, Annals of Philosophy, 1825; Agassiz.
Propleuridæ; Cope, Sillim. Am. Jour. Sci., 1870, p. 137.
Trionychidæ; Gray, Bell, Dum., Bibr., Agassiz.
Emydidæ; Emydidæ and Chelydridæ, Agassiz.
Adocidæ; Cope, Proceed. Am. Philos. Soc., 1870, November.
Cinosternidæ; Agassiz, Contrib. Nat. Hist. U. S.; Cope, Leconte (part).

Testudinidæ; Gray, Agassiz, Cope emend.
Pleurosternidæ; Cope, Proceed. Acad. Nat. Sci., Phila., 1868, October.

3. Pleurodira.

Duméril, Bibron; *Chelyoidæ*, Agassiz.
Podocnemididæ; Cope, Proceed. Acad. Nat. Sci., Phila., 1868, October; Peltocephalidæ, Gray.
Chelydidæ; Gray, Proceed. Zoöl. Soc., London, 1869; Cope, l. c., 1868.
Hydraspididæ; Cope, l. c.; Gray, l. c.
Pelomedusidæ; Cope, l. c., 1865, p. 185, 1868, p. 119.
Sternothæridæ; Cope, l. c., 1868, p. 119.

IX. LACERTILIA.

Owen, Cope.

1. Rhiptoglossa.

Acrodonta Rhiptoglossa; Wiegmann, Fitzinger, Cope. *Chamæleonida;* Müller.
Chamæleontidæ; Wiegmann, Gray, et auctorum.

2. Pachyglossa.

Cope; *Acrodonta Pachyglossa*, Wagler, Fitzinger. Cope, Proceed. Acad. Nat. Sci., Phila., 1864, p. 226.
Agamidæ.

3. Nyctisaura.

Gray; Catal. Sauria Brit. Mus.; Cope, l. c.
Gecconidæ; Gray, et auctorum.

4. Pleurodonta.

Cope, Proceed. Acad. Nat. Sci., Phila., 1864, p. 226.

a. Iguania.

Anolidæ; Cope, l. c., pp. 227, 228.
Iguanidæ; Cope, l. c., pp. 227, 228; Iguanidæ (pars), auctorum.

b. Diploglossa.

Anguidæ; Cope, l. c.
Gerrhonotidæ; Cope, l. c.; *Zonuridæ* (part), Gray.
Xenosauridæ; Cope, l. c., 1866, p. 322.
Helodermidæ, Gray; Catal. Sauria Brit. Mus.; Cope, l. c., 1864, p. 228, 1866, p. 322.

c. Thecaglossa.

Wagler, Fitzinger, Cope.
Varanidæ.

d. Leptoglossa.

Wiegmann, Fitzinger, Cope.
Teidæ; *Teidæ* and *Ecpleopodidæ*, Peters, Cope, Proceed. Acad. Nat. Sci., Phila., 1866, p. 228; *Teidæ Anadiidæ Cercosauridæ Riamidæ*, Gray.
Lacertidæ; Gray; Catal. Sauria; Cope, l. c.; Lacertidæ et *Cricosauridæ*, Peters; *Xantusiidæ*, Baird.
Zonuridæ; *Zonuridæ* (part), Gray; *Lacertidæ* (part), Cope.
Chalcididæ; Gray, l. c.; Cope, l. c.
Scincidæ; Gray, l. c.; Cope, l. c.
Sepsidæ; Gray, l. c.; Cope, l. c.

e. Typhlophthalmi.

Cope, Proceed. Acad. Nat. Sci., Phila., 1864, p. 228; Do. (pars), Duméril et Bibron. Erpet. Gen.
Anelytropidæ; Cope, l. c. name; *Typhlinidæ*, Gray.
Acontiidæ; Gray; Catal. Brit. Mus.; Cope, l. c., 1864, p. 230.
Aniellidæ; Cope, l. c., 230.

5. Ophiosauri.

Cope, l. c., Merrem; *Annulati*, Wiegmann; *Ptychopleures Glyptodermes*, Dum., Bibr.; *Amphisbænoidea*, Müller.
Amphisbænidæ; — æ, Wiegmann, Fitzinger.
Trogonophidæ; *Trogonophes*, Wiegmann, Fitzinger.

X. PYTHONOMORPHA.

Cope, Trans. Am. Philos. Soc., 1870, p. 175; Proceed. Boston Nat. Hist. Soc., 1869, p. 251; *Lacertilia Natantia*, Owen; Palæontograph. Society, Cretaceous Reptiles.
Clidastidæ; Cope, l. c., p. 258.
Mosasauridæ; Cope, l. c., p. 260.

XI. OPHIDIA.

1. Scolecophidia.

Duméril; *Scolecophidia* et *Catodonta*, Cope, Proceed. Acad. Nat. Sci., 1864, p. 230.
Typhlopidæ; *Epanodontiens*, Dum., Bibr.
Stenostomidæ; *Catodontiens*, Dum., Bibr.; *Catodonta*, Cope, l. c.

2. Tortricina.

Müller, Cope, l. c.
Tortricidæ.
Uropeltidæ; *Uropeltacea*, Peters; *Rhinophidæ*, Gray.

3. Asinea.

Müller, Cope.

a. Peropoda.

Müller.
Xenopeltidæ; Cope, l. c.; Günther, Reptiles British India.
Pythonidæ; Cope, l. c.; *Holodontiens*, Dum., Bibr.
Boidæ; Cope, l. c.; *Aproterodontiens*, Dum., Bibr.
Lichanuridæ; Cope, Proceed. Acad. Nat. Sci., Phila., 1868, p. 2.

b. Colubroidea.

Achrochordidæ; Cope, l. c., p. 231; *Achrochordiens*, Dum., Bibr.

Homalopsidæ; Cope, Proceed. Acad. Nat. Sci., Phila., 1864, p. 167; *Natricidæ* (pars), Günther; *Potamophilidæ*, Jan.

Colubridæ; *Asinea* Group *β-bb*, Cope, Proceed. Acad. Nat. Sci., Phila., 1864, p. 231; *Calamaridæ, Oligodontidæ, Coronellidæ, Colubridæ, Dryadidæ, Dendrophidæ, Dryiophidæ, Psammophidæ, Lycodontidæ, Scytalidæ, Dipsadidæ*, etc., Günther, Catal. Brit. Mus., et op. alt.

Rhabdosomidæ; *Calamaridæ* (part), Günther.

4. Proteroglypha.

a. Conocerca.

Elapidæ; Cope, l. c., p. 231; *Elapidæ* (pars), Günther, l. c.
Najidæ; Cope, l. c.; *Elapidæ* (pars altera), Günther, l. c.

b. Platycerca.

Hydrophidæ; *Hydridæ*, Gray; *Hydrophidæ*, Schmidt, Fischer, Günther. Cope, Proceed. Acad. Nat. Sci., Phila., 1869, p. 75, 1864, p. 231.

5. Solenoglypha.

Duméril, Bibron; *Viperidæ*, Cope, Proceed. Acad. Nat. Sci., 1859, p. 333.

Atractaspididæ; Günther; Catal. Brit. Mus.; Cope, l. c., 1859, p. 334.

Causidæ; Cope, l. c., 1859, p. 334.

Viperidæ; Gray; Catal. Brit. Mus., p. 18; Cope, l. c.; Günther, Reptiles British India.

Crotalidæ; Gray, l. c., Cope, l. c., Günther, l. c., et auctorum.

8. *Critical Remarks on the System.*

1. In the "Transactions of the American Philosophical Society," 1869, part I. (August), I proposed a system in which the primary groups of the Reptilia were defined anew, and understood in some measure differently from those proposed by Owen. The system of the latter author, and that of Von Meyer, were the only ones extant previously; and additional discovery necessitated some modifications, while the meritorious portions of both it was intended to preserve. The groups, perhaps equivalent to "orders," retained, were the Ichthyopterygia, Archosauria, Testudinata, Pterosauria, Lacertilia, Pythonomorpha, and Ophidia. The form of attachment of the quadrate bone was regarded, after Johannes Müller, as an element of prime importance in the estimate of affinities, and of nearly equal value, the differentiation of distal elements of limbs, the opisthotic bone, the mode of attachment of ribs, etc.

Another systematic grouping of the orders was proposed by Professor Huxley in the "Journal of the Geological Society," London, 1869 (November), in which the position and character of the rib articulations to the vertebral centra were used exclusively in discrimination of the groups. The subclasses proposed were the Suchospondylia, which is our Archosauria; the Perospondylia, our Ichthyopterygia; * the Herpetospondylia, corresponding to our orders Ophidia, Pythonomorpha, Lacertilia, with the addition of the Sauropterygia. The last group is rendered unnatural by the presence of the latter order, which possesses the closely articulated quadrate bone of the Archosauria. I therefore omit it, and retain the three orders remaining, in one division, which has already been named by Müller the Streptostylica. Huxley's fourth subclass, the Pleurospondylia, includes the Testudinata only. This group I also recognized in the original memoir quoted, and I accept it with

* Some criticisms of Professor Huxley's in this essay, on my determination of the structures and relations of the Dinosauria, are so inapposite as to require notice. He quotes me as saying of the astragalus of Lælaps, that "one other example of this structure is known in the Vertebrata;" and adds, "but I shall show immediately that the astragalus is altogether similar in the commonest birds, and probably in the whole class Aves." This statement is so precisely the reverse of the fact, that I can only suppose it to be an inadvertence, or a *double entendre*, the latter being an impossibility in so fair a man as Professor Huxley. On page 85 he says: "Professor Cope has distinguished Compsognathus as the type of a division Ornithopoda, from the rest of the Dinosauria, which he terms Goniopoda (on the structure of the foot, etc.)... It seems to me precisely by the structure of the foot that Compsognathus is united with, instead of being separated from,

new definition, so much so indeed as to constitute a substitution. The Rhynchocephalia (an order which Huxley has not recognized), Testudinata, and Sauropterygia agree in the essential structures of the quadrate element, and the simplicity of the rib attachment; they also agree in the abdominal ribs and plane vertebral centra. The capitular rib articulations are on processes in the last, in the Testudinata in pits, but in Sphenodon almost sessile on the centra. If Rhynchosaurus be a Rhynchocephalian, it has tortoise-like jaws; so has the Sauropterygian Placodus in some respects. Natatory fins of Plesiosaurus, etc., are repeated in the turtle Sphargis. So, though this association into the subclass which I have called Synaptosauria appears at first sight unnatural, it probably has a basis in nature.

2. The Ornithochiræ of Seeley do not appear to belong to the Ornithosauria, but to the Birds, where they would enter the subclass Saururæ with the Archæopteryx. This depends on the accuracy of Seeley's statement that the metatarsi are united, and there seems to be no reason to doubt it. This learned author does not state whether the tarsal bones are distinct or not; though confluent metatarsi suggest union of these also, since the Dinosauria lose the distinctness of the tarsals, and preserve separate metatarsals. This group will be annectant to the Reptilia by their near allies the Ornithosaurian group of Dimorphodontæ of Seeley.

3. The arrangement of the Lacertilia is the same as that proposed by the author in 1864, with three exceptions. The Rhiptoglossa are separated from the Pachyglossa by a wider interval, and the two groups are regarded as of primary value. In the system quoted they are united into one primary group, — the Acrodonta. Secondly, the Sphenodontidæ (Hatteriidæ) are removed from the

the Ornithoscelida." I united Compsognathus with the Dinosauria in 1867, on account of the foot structure (as quoted by Professor Huxley, p. 24), but regarded its subordinate modification of arrangement as indicative of a subordinate division, Symphypoda. This is exactly the course adopted by Professor Huxley in 1869, only he changes the name of Symphypoda to Compsognatha, and gives different characters to it. As to the groups Ornithopoda and Goniopoda, as ascribed to me, they cannot be found in my papers. On page 24 Professor Huxley supports Cuvier's determination of the position of the tibia in Dinosauria, as different from mine, observing that "Cuvier was right from a morphological point of view, when he declared the tibia to be laterally compressed," etc. This point I never contested; but that Cuvier was wrong so far as actual position is concerned, as I have proposed, is evidently Professor Huxley's opinion, since he arranges the tibia in his descriptions and plates precisely as I did in 1867.

Pachyglossa, and associated with certain extinct forms into the order Rhynchocephalia. This is in consequence with the full statement of its structural characters by Günther, and I accept the new order proposed for it by this author, with some change of diagnosis. Third, the Zonuridæ are regarded as distinct from the Lacertidæ on account of their papillose tongue.

4. In the Ophidia, the Typhlopidæ and Stenostomidæ are united into one order, the Scolecophidia, as already done by Duméril and Bibron. I separated them in the system proposed in connection with that of the Lacertilia in 1864, on account of the supposed absence of the prefrontal bone in Typhlops while it is present in Stenostoma. I find, however, that the large bone I supposed to be maxillary in Typhlops, is really the prefrontal, and that the maxillary is concealed on the inferior face of the skull, being represented by a narrow strip alongside of the vomer.

9. *On the Rhynchocephalia and supposed Lacertilia of the Trias and Permian.*

The existence of Lacertilia in the Trias has been asserted by Professor Huxley, as indicated by the genera Hyperodapedon, Telerpeton, Rhynchosaurus, and Saurosternum.* For us the evidence furnished by these and other genera is conclusive only as to the presence of the Rhynchocephalia in beds of that age, while the existence of the Lacertilia remains undecided. The other genera are from Germany; viz., Proterosaurus, Sphenosaurus, and Phanerosaurus, of Meyer. Of these the first two are believed by Huxley to be Lacertilia.†

The characters of the Rhynchocephalia have been in part pointed out in the preceding pages. Other features, especially of the soft parts, can be learned by reference to Günther's Monograph of Sphenodon, already quoted.

Of the above genera, Hyperodapedon has the remarkable palatal structure characteristic of Sphenodon, and entirely unknown among the Lacertilia, and I have little doubt that the genus belongs to the same order; viz., the Rhynchocephalia. In all of the remaining genera, the vertebræ are flat or sub-biconcave as in Rhynchocephalia, and not procœlian as in Lacertilia. In defence of the position of Telerpeton as a Lacertilian, Professor Huxley cites the biconcave vertebræ of the Gecconidæ. These are, however, fish-like, and enclose within the adjacent conic cavities of

* Jour. Geol. Soc., Lond., 1869, p. 49. † Ibid., p. 87.

two centra a mass of cartilage. In the Batrachia, the ossification of this mass produces the ball which adheres to the centrum in front or behind, producing the procœlian or opisthocœlian vertebra. The vertebræ of Gecconidæ are therefore probably in the embryonic form of those of the other Lacertilia. Not so, however, with the Triassic genera in question. According to Meyer's figures, they are nearly plane, like those of Sphenodon and Dinosauria; and were probably developed round the chorda dorsalis, without retention of included ball.

In Phanerosaurus, the neural arches are united to the body by suture, a character unknown in the Lacertilia. In general the vertebræ by which the genus is known might as well belong to a Sauropterygian. In Proterosaurus (See Von Meyer's "Saurier aus dem Kupferschiefer," Plates), the forms of the inferior pelvic bones and the presence of inferior abdominal ribs, are so entirely unlike any thing in the Lacertilia, and so much like the same parts in Sphenodon, that this genus also, I have no doubt, is a Rhynchocephalian. Every thing is in favor of the supposition that Rhynchosaurus and Sphenosaurus are Rhynchocephalians, since the parts preserved correspond with those of known types of that order, and none of the special peculiarities of Lacertilians, as distinguished from the former, have been discovered.

The only genera remaining are Saurosternum (Huxl.) and Telerpeton (Mant.). In the latter genus the palatine bones are said not to be separated by the pterygoids, and there is no quadratojugal represented by Huxley: if these characters exist, it suggests the Lacertilia rather than Rhynchocephalia. The latter is the more important point; but further examination is necessary to decide on it, as the postorbital arch is also omitted in the figure, which is possibly an inaccuracy, consequent on the state of the specimen. The form is in its dentition equally like the Lacertilian Uromastix and the Rhynchocephalian Sphenodon; but the transverse direction of the parieto-squamosal arch, and the plane or concave articulations of the vertebral centra, are those of the latter, not of the former.

As to Saurosternum, not enough is known of the only specimen to ascertain whether it belongs to the Lacertilia or Rhynchocephalia. There is no cranium, and the parts preserved or described are as characteristic of one order as the other.

10. *Stratigraphic Relation of the Orders of Reptilia.*

This is most readily shown in tabular form, as follows:—

Present				Rhynchocephalia		Crocodilia		Testudinata	Lacertilia		Ophidia
Pliocene						Crocodilia		Testudinata	Lacertilia		Ophidia
Miocene						Crocodilia		Testudinata	Lacertilia		Ophidia
Eocene						Crocodilia		Testudinata	Lacertilia		Ophidia
Cretaceous	Ornithosauria	Dinosauria				Crocodilia	Sauropterygia	Testudinata	Lacertilia	Pythonomorpha	
Jurassic	Ornithosauria	Dinosauria			Ichthyopterygia	Crocodilia	Sauropterygia	Testudinata	Lacertilia		
Triassic		Dinosauria	Anomodontia	Rhynchocephalia	Ichthyopterygia	Crocodilia	Sauropterygia	?	?		
Permian			?	Rhynchocephalia							

It will be observed, by this table, that the most specialized Reptilian order, the Ophidia, appeared last in time in the Eocene period; and that those which constitute the line of connection with the generalized reptiles appeared earlier as they approached the latter,— the Pythonomorpha in Cretaceous, and Lacertilia in Jurassic times. The Reptilian groups most specialized in bird characters (Ornithosauria and Dinosauria) appear on the other hand very early; the first and most Mammalian also,— the later of the two,— in Jurassic Beds. The Trias gives us in the Anomodontia and Ichthyopterygia, the two most generalized and lowest orders; while their contemporary, the Rhynchocephalia, almost as much generalized in Reptilian features proper, was already represented in the Trias. Strangely enough this order yet exists in the living Sphenodon of New Zealand. The Crocodilia, rather specialized in bird characters, accompanies the last in this wonderful persistency, beginning also in the Trias.

The inquiry as to the truth of the proposition that the more ancient types of animals are more generalized, and therefore more embryonic in the characters of a special nature* which characterized groups later introduced, is answered in a very imperfect way in the affirmative. It is like the shadow of a truth whose substance will shortly come before us. But when we come to compare the subdivisions of the orders themselves with each other, and with those of other orders, as we pass backwards in time, the weight of the affirmative answer to the above proposition is greatly increased. The oldest Ophidia are boæform, therefore approaching Lacertilia and Pythonomorpha. The oldest Tortoises have generally the most incomplete carapace and plastron; among them the Psephoderma allied to Sphargis, without carapace, and thus the most lizard-like of the order. The Lacertilia of European Jurassic strata are, some of them at least, acrodont, apparently Pachyglossa (*e. g.*, Acrosaurus), and, as such, nearer the Rhynchocephalia, which preceded them in time. The position of Homorosaurus and Piocormus is not determinable, as the dentition cannot be understood from the descriptions and figures of Wagner. The form of the mesosternum of the former refers it to either the Pachyglossa or Iguania, as I understand those groups. It may be assumed that since the order Lacertilia has diverged from the line of other Reptilia, while it took on in its special peculiarities it lost in the features characterizing the main

* The identity of these two propositions has not always been noticed by authors.

series with a higher tendency or terminus, thus *retrograding* in one sense. This is seen in the shortened sacrum, pleurodontu dentition, etc.

The Crocodilia of the Jurassic do not possess the ball and socket-jointed vertebræ of the recent genera, and exhibit the plane articular faces of all the Jurassic and Triassic Reptilia. Their basicranial region is also plane like that of other orders, instead of vertical as in the recent forms. The Triassic Crocodiles are still more generalized. Their ribs are extended to the pelvis, as in Dinosauria and Anomodontia: there are often three sacral vertebræ, an approach to the long sacrum of the same orders. The femur, with third trochanter, is an approach to that of the Dinosauria; and finally the position of the nostrils near the orbits (Belodon) is a Sauropterygian feature. In the Sauropterygia the shortened vertebral column, and long muzzle (Pistosaurus) in the oldest types (Triassic), are approximations to the Crocodilia. The Dinosauria display an increasingly Crocodilian character as we pass into the Triassic period. The femur (Palæosaurus, Megadactylus) loses the bird-like head, and assumes the ill-defined convexity of the Crocodiles; the tibia (Plateosaurus) loses the bird-like "spine," or crest. The ilium is shorter (Palæosaurus). Every student of the subject knows how much more difficult is the separation of the bones of Sauropterygia, Crocodilia, Anomodontia, and Dinosauria, of the Trias, than those of the Cretaceous. There are types allied to the Rhynchocephalia, whose systematic position is doubtful, owing to the generalized character of the parts we possess. Thus the Rhynchosaurus of the Trias of England is allied to that order, and to the Anomodontia. The Rhopalodon of the Permian has a large canine tooth, like the single one possessed by the Anomodontia; but with others associated, like those of the Rhynchocephalia. The Triassic Sauropterygia and Rhynchocephalia also agree in the anterior production of the pterygoid bones between the palatines to the vomer. Compare, for this point, Hyperodapedon and Nothosaurus.

We learn from such considerations as the above, and similar ones derived from the study of the Mammalia, that the successional relation of the faunæ of the periods in geologic time is more strikingly exhibited by the subordinate contents of the orders than by the orders themselves, in relation to each other. From this we decide that we must look for the origin of the orders in periods prior to those in which we now know them, if, as some suppose,

they originated in still more generalized types. This accords with Huxley's view of the period of origin of the Mammalian orders.

It must also be remembered that the above deduction as to geological distribution is precisely that of geographical distribution; *i. e.*, that the homologous groups of different continents are not orders, but subordinate divisions of orders, the orders being universally distributed. This coincidence is remarkable, and justifies the view I have taken of the origin of higher types on the basis of retardation and acceleration, and of the nature of synchronism.*

Note in reply to Dr. Seeley's remarks on my interpretation of the structure of the cranium of Ichthyosaurus.

A brief abstract of the portions of the preceding paper, which relate to Ichthyosaurus and Lystrosaurus, having been published in the "American Naturalist," for 1870, Dr. Seeley publishes a criticism of the statements and conclusions therein contained, in the "Annals and Magazine of Natural History" for April, 1871. I will briefly reply to these remarks; and commence by saying that he discovers some errors in determinations of bones of the cranium of Ichthyosaurus, which are due to errors of the artist and proof reader; such are more likely to occur in an abstract issued early in a periodical, than in the essay itself. Thus he finds the lettering of the maxillary and lachrymal bones to be exchanged. This, as he supposes, is the artist's error, and one which was corrected on the proof which was not received in time. He also finds the nomenclature of the elements of the mandible to be erroneous. This resulted from a misconception by the artist of the lettering on my original drawing, which I find to be correct, and which in the present memoir is correctly copied. In the same way the small "supersquamosal" will be found described in the present paper.

The question as to the determination of the bones forming the roof of the cranium receives new light from Dr. Seeley's remarks. This has been much needed by American naturalists, for I have been unable to find in the whole range of the literature of the subject an English description of the osteology of the head of Ichthyosaurus, which is at all complete; and the figures are not more instructive. Dr. Seeley's statement, that the flat bone on the inner side of the temporal fossa, continuous in our specimen with the squamosal, is usually separated from the latter by suture, is valuable, and suggests that the element may be parietal and not homologous with the similar plate in Dicynodonts. This possibility has existed in my mind all along, but what are thus probably sutures in two of our specimens have looked as much like fractures. As to the bones suspected to be nasals, I find that of the left side present in a specimen of *I. intermedius*, besides that from Barrow, but wanting in one of *I. tenuirostris*. As observed by Seeley, the absence of a bone in a fossil has little weight in evidence of its

* Origin of Genera, 1868; Hypothesis of Evolution, 1870.

non-existence, as compared with its presence in evidence of its existence. Nevertheless, its absence in so many specimens as Dr. Seeley has had the opportunity of examining renders it necessary to ascertain whether the element in question is a dismemberment of some other bone or not. And this I must leave to those who have more extended material for examination. Dr. Seeley's objections to my determination of the frontals (? nasals) are not weighty, and are anticipated in the memoir itself.

On the whole, the probabilities of the Cuvierian nomenclature of the bones of the cranial roof being correct is rather increased by Dr. Seeley's remarks, but I have not been able to discover that any one has correctly determined the squamosal, quadratojugal, opisthotic, and stapedial bones before the reading of my paper.

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2. On the Embryology of Limulus Polyphemus. By A. S. Packard, Jr., of Salem, Mass.

(Abstract.)

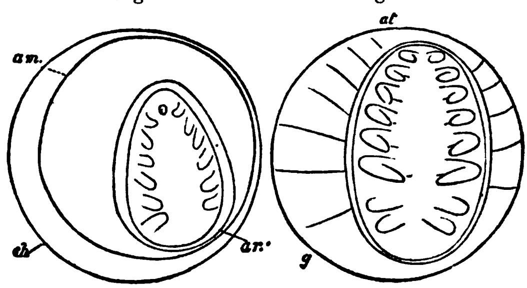
The eggs on which the following observations were made were kindly sent me from New Jersey, by Rev. Samuel Lockwood, who has given an account of the mode of spawning, and other habits, in the "American Naturalist." They were laid on the 16th of May, but it was not until June 3d that I was able to study them. The eggs measure .07 of an inch in diameter, and are green. In the ovary they are of various hues of pink and green just previous to being laid, the smaller ones being, as usual, white. The eggs are simple, the ovarian eggs being formed of a single cell. The yolk is dense, homogeneous, and the yolk granules, or cells, are very small, and only in certain specimens, owing to the thickness and opacity of the egg-shell, could they be detected.

Not only in the eggs already laid, but in unfertilized ones taken from the ovary the yolk had shrunken slightly, leaving a clear space between it and the shell. Only one or two eggs were observed in process of segmentation. In one the yolk was subdivided into three masses of unequal size. In another the process of subdivision had become nearly completed.

In the next stage observed, the first indications of the embryo consisted of three minute, flattened, rounded tubercles, the two anterior placed side by side, with the third immediately behind them. The pair of tubercles probably represent the first pair of limbs, and the third, single tubercle the abdomen. Seen in out-

line the whole embryo is raised above the surface of the yolk, being quite distinct from it, and of a paler hue. In more advanced eggs three pairs of rudimentary limbs were observed, the most anterior pair representing the first pair of limbs (false mandibles of Savigny) being much smaller than the others. The mouth

Fig. 1. Fig. 2.



Embryo of Limulus.

opening is situated just behind them. In a succeeding stage (fig. 1, *ar*, areola; *am*, inner egg membrane; *ch*, chorion) the embryo forms an oval area, surrounded by a paler colored areola, which is raised into a slight ridge. This areola is destined to be the edge of the body, or line between the ventral and dorsal sides of the animal. There are six pairs of appendages, forming elongated tubercles, increasing in size from the head backwards; the mouth is situated between the anterior pair. The whole embryo covers but about a third of that portion of the yolk in sight. At this time the inner egg membrane (blastoderm-skin?) was first detected.

The outer membrane, or chorion, is structureless; when ruptured, the torn edges show that it is composed of five or six layers of a structureless membrane, varying in thickness. The inner egg membrane is free from the chorion, though it is in contact with it. Seen in profile it consists of minute cells which project out, so that the surface appears to be finely granulated. But on a vertical view it is composed of irregularly hexagonal cells, sometimes five-sided, and rarely four-sided, hardly two cells being alike. The walls of the cells appear double, and are either strongly waved, or have from three to five long slender projections, with the ends sometimes knobbed, directed inwards. These cells are either packed closely together, or separated by quite a wide interspace.

In a subsequent stage (fig. 2) the oval body of the embryo has increased in size. The segments of the cephalothorax are indicated, and the legs have grown in length, and are doubled on them-

selves. But the most important change is in the small size of the rudiments of the mandibles, compared with the remaining five pairs of limbs; and the origin of two pairs of gills, forming pale oblique bands between the sixth pair of legs and the end of the abdomen, which forms a narrow semicircular area.

A later stage is signalized by the more highly developed dorsal portion of the embryo, and the increase in size of the abdomen and the appearance of nine distinct abdominal segments. The segments of the cephalothorax are now very clearly defined, as also the division between the cephalothorax and abdomen, the latter being now nearly as broad as the cephalothorax, the sides of which are not spread out as in a later stage. At this stage the egg-shell has burst, and the inner egg membrane increased in size

Fig. 3.

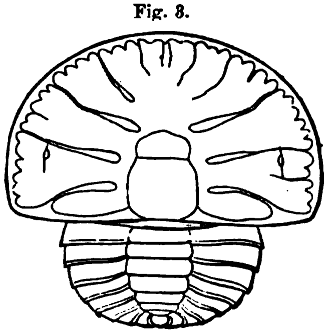
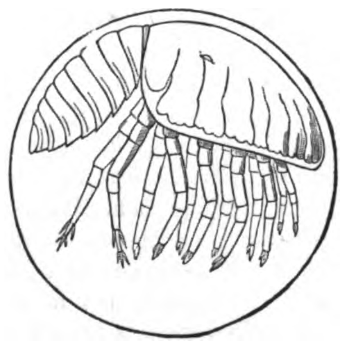


Fig. 4.



Embryo of Limulus just before hatching.

several times exceeding its original bulk, and has admitted a corresponding amount of liquid, in which the embryo revolves. At a little later period the embryo throws off an embryonal skin, the thin pellicle floating about in the egg.

Still later in the life of the embryo the claws are developed, an additional rudimentary gill appears, and the abdomen grows broader and larger, with the segments more distinct; the heart also appears, being a pale streak along the middle of the back extending from the front edge of the cephalothorax to the base of the abdomen.

Just before hatching the cephalothorax spreads out, the whole animal becomes broad and flat, the abdomen being a little more than half as wide as the cephalothorax. The two eyes and the pair of ocelli on the front edge of the cephalothorax are distinct;

the appendages to the gills appear on the two anterior pairs; the legs have increased in length, though only a rudimentary spine has appeared on the coxal joint, corresponding to the numerous spines in after life. The trilobitic appearance of the embryo (fig. 3, top; 4, side view) is most remarkable. It also now closely resembles the Xiphosurian genus Bellinurus. The cardiac, or median, region is convex and prominent. The lateral regions are more distinctly marked on the abdomen than on the cephalothorax. The six segments of the cephalothorax can, with care, be distinguished; but the nine abdominal segments are most clearly demarked, and in fact the whole embryo bears a very near resemblance to certain genera of Trilobites, as Trinucleus, Asaphus, and others.

In about six weeks from the time the eggs are laid the embryo hatches. It differs chiefly from the previous stage in the abdomen in being much larger, scarcely less in size than the cephalothorax; in the obliteration of the segments, except where they are faintly indicated on the cardiac region of the abdomen; and the gills are much larger than before. The abdominal spine is very rudimentary, forming a lobe varying in length, but scarcely projecting beyond the edge of the abdomen. It forms the ninth segment. The young swim briskly up and down the jar, skimming about on their backs, by flapping their gills, not bending their bodies. This mode of swimming corresponds to that of Apus. In a succeeding moult, which occurs between three and four weeks after hatching, the abdomen becomes smaller in proportion to the cephalothorax, and the abdominal spine is prominent, being ensiform, and about three times as long as broad. At this, and also in the second or succeeding moult, which occurs about four weeks after the first moult, the young Limulus doubles in size.

Conclusions.—The eggs are laid in great numbers in the sand, the male probably fertilizing them after they are dropped. This is an exception to the usual mode of oviposition in Crustacea; Squilla and a species of Gecarcinus being the only exception known to me to the law that the Crustacea bear their eggs about with them. Besides the structureless, dense, irregularly laminated chorion, there is an inner egg membrane composed of rudely hexagonal cells; this membrane increases in size with the growth of the embryo, the chorion splitting and being thrown off during the latter part of embryonic life. Unlike the Crustacea generally, the primitive band is confined to a minute area, and rests on top of the yolk, as in the spiders and scorpions, and certain Crustacea; *i. e.*,

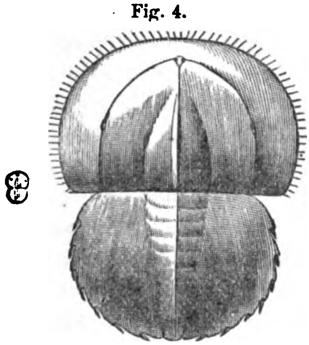
Eriphia spinifrons, *Astacus fluviatilis*, *Palæmon adspersus*, and *Crangon maculosus*, in which there is no metamorphosis.

The embryo is at first a Nauplius; it sheds a larval skin about the middle of embryonic life.

This larval skin corresponds in some respects to the "larval skin" of German embryologists. It is a true moult however, the skin being cast after the feet have become quite large, and the larva has passed into the subzoëa stage.

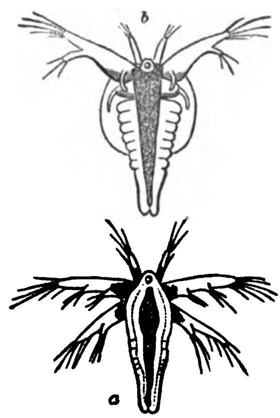
The recently hatched young of Limulus (fig. 4) can scarcely be considered a Nauplius, like the larvæ of the Phyllopoda, Apus

Fig. 4.



Larva of Limulus, natural size, and enlarged.

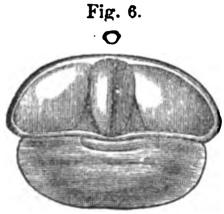
Fig. 5.



a, Larva of Apus.
b, Larva of Branchipus.

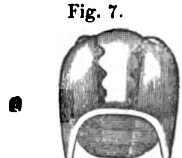
(fig. 5, *a*), and Branchipus (fig. 5, *b*), but is to be compared with those of the Trilobites, as described and figured by Barrande (fig. 6, larva of *Trinucleus ornatus;* fig. 7, larva of *Sao hirsuta;* fig. 8, larva of *Agnostus nudus*), which are in Trinucleus and Agnostus born with only the head and pygidium, the thoracic segments being added during after life. The circular larva of *Sao hirsuta*, which has no thorax, or, at least, a very rudimentary thoracic region, and no pygidium, approaches nearer to the Nauplius form of the Phyllopods, though we would contend that it is not a Nauplius. It should rather be compared to the larva or zoëa of Decapoda, and may perhaps be called a retarded zoëa.

Fig. 6.



Larva of Trinucleus ornatus, natural size, and enlarged.

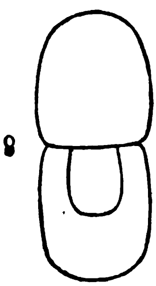
Fig. 7.



Larva of Sao hirsuta, natural size, and enlarged.

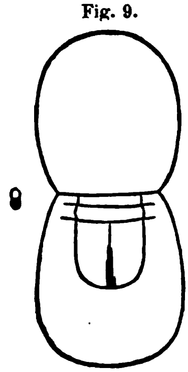
Indeed a study of the embryology of Limulus, as well as its anatomy, leads me to consider, as several authors have done, from Savigny and Van der Hoeven down to the present time, the anterior division of the body as a cephalothorax, the posterior division being the abdomen. Latreille, Milne-Edwards, and more recently Mr. Henry Woodward,* the distinguished palæontologist, have regarded the anterior division of the body as the head, and the posterior division as embracing the thorax and abdomen; the last three segments in Mr. Woodward's opinion, including the telson, representing the abdomen. Professor Dana, in his great work on the Crustacea of the United States Exploring Expedition, regards the telson as the abdomen, the remainder of the animal being the cephalothorax. Against this view I think can be brought the embryological facts already stated. The germ first starts as a Nauplius, and just previous, to moulting a larval skin in the egg, the abdomen is differentiated from the cephalothorax. In this latter region (composed of six segments) are contained not only the eyes, simple and compound, but all the ambulatory appendages, which surround the mouth and are true maxillipeds; no antennæ or thoracic appendages being developed, unless the last pair of ambulatory feet be considered as thoracic members. This region contains the stomach and a considerable portion of the intestine, and the liver, which opens into the intestine near the middle of the cephalothorax, sending but a single pair of biliary tubes into the abdomen. The anterior half of the dorsal vessel, with two pairs of arteries, and two pairs of valvular openings, is situated in the cephalothorax. Lastly, the genital openings in both sexes are situated on the first pair of abdominal lamellate appendages, the testes and ovaries lying wholly in the cephalothorax; the ovaries, when distended with eggs, filling up the front of the cephalothoracic shield.

Fig. 8.



Larva of Agnostus nudus, nat. size, and enlarged.

Fig. 9.



Adult Agnostus nudus, nat. size, and enlarged.

The abdomen consists of nine segments, the long spine-like tel-

* On some Points in the Structure of the Xiphosura. Quarterly Journal of the Geological Society of London, for February, 1867.

son forming the ninth, as seen plainly in the embryo. The abdominal cavity is small, the abdomen being very thin, and mainly filled with the muscles attached to the lamellate feet.

There are, then, in Limulus, probably no thoracic feet, comparable with those of the Decapods and the Tetradecapods; and the thoracic region (as much of it as exists) is merged with the head, in fact never becoming differentiated from the head proper. Thus we have in Limulus a crustacean with the body divided into two regions: a cephalothorax (the thorax being potential, viewed externally, with no appendages or segments to indicate its existence) and a nine-jointed abdomen.

This disposition of the body-segments is paralleled by the zoëa, or young, of the Decapods. In the freshly hatched zoëa the body is divided into two regions: the cephalothorax, with no trace at first of thoracic segments, or thoracic appendages (the two pairs of large feet being deciduous mandibles and maxillæ), the thorax not being yet differentiated; and a five to seven jointed abdomen. The size of the cephalothorax, as compared with the abdomen, varies greatly in the different forms of zoëæ, some zoëæ strongly resembling Eurypterus in the small cephalothorax. After the first moult five pairs of rudimentary thoracic limbs arise at the hinder portion of the cephalothorax, thus proving our statement that the cephalothorax of Limulus, and consequently the so called "head" of Eurypterus and Pterygotus, combines a head with a potential thorax, the latter never becoming differentiated in subsequent moults.

In the Trilobites, however, if the late discovery of Mr. Billings is correct, the thoracic segments bearing jointed feet are developed; though, as shown by Barrande, the larval trilobite is hatched either without any, or with but a single, thoracic segment. Limulus, Eurypterus, Pterygotus, and their allies (Huxley has aptly compared the Eurypteridea to a zoëa), with the Phyllopods, may be considered as virtually in a zoëa stage, or, to be more precise (since they lack many important characters of zoëæ), retarded zoëæ; and the ancestry of the Decapods may be thus traced to the Branchiopods.

The larva passes through a slightly marked metamorphosis. It differs from the adult simply in possessing a less number of abdominal feet (gills), and in having only a very rudimentary spine. Previous to hatching it strikingly resembles Trinucleus and other Trilobites, suggesting that the two groups should, on embryonic and structural grounds, be included in the same order, especially

now that Mr. E. Billings * has attempted to show that Asaphus possessed eight pairs of five-jointed legs of uniform size. The trilobitic character of the body, as shown in the prominent cardiac and lateral regions of the body, and the well-marked abdominal segments of the embryo, the broad sternal groove, and the position and character of the eyes and ocelli, strengthen this view. The organization and the habits of Limulus throw much light on the probable anatomy and habits of the Trilobites. The correspondence in the cardiac region of the two groups shows that their heart and circulation was similar. The position of the eyes shows that the Trilobites probably had long and slender optic nerves, and indicates a general similarity in the nervous system. The genital organs of the Trilobites were probably very similar to those of Limulus, as they probably could not have united sexually; and the eggs were probably laid in the sand or mud, and impregnated by the sperm cells of the male, floating free in the water.

The muscular system of the Trilobites must have been highly organized as in Limulus, as like the latter they probably lived by burrowing in the mud and sand, using the shovel-like expanse of the cephalic shield in digging in the shallow paleozoic waters after worms and stationary soft-bodied invertebrates, so that we may be warranted in supposing that the alimentary canal was constructed on the type of that of Limulus, with its large, powerful gizzard, and immense liver.

The order Branchiopoda may be subdivided then into perhaps four suborders: (1) the Phyllopods; (2) the Clodocera; (3) the Trilobites, or Paleodes; and (4) the Pœciloptera, comprising the Limuli and Eurypteri.

Speculating on the ancestry of the members of the order of Branchiopoda, they may be traced to a common Nauplius form, as Fritz Müller, Haeckel, and Dohrn have done for the Crustacea generally. This Nauplius form may have existed in the Laurentian period, as we already find highly organized Trilobites, Phyllopods, and Ostracodes in the lower Silurian strata. The

* Proceedings of the Geological Society of London. Reported in "Nature," June 2, 1870. In this communication Mr. E. Billings announces the important discovery of a specimen of *Asaphus platycephalus*, showing that the animal possessed eight pairs of five-jointed feet, widely separated at their insertions by a broad sternal groove.

While this paper is going through the press we notice that Messrs. Dana, Verrill, and Smith, however, from an examination of Mr. Billings' specimen, at the latter's request, question whether there be appendages at all. (Amer. Journ. of Science, May, 1871.)

modern Phyllopods, such as Apus and Branchipus, may have descended, perhaps, by two parallel lines of descent, from certain Silurian Copepoda and Ostracoda. The origin of these forms may be accounted for rather by a process of acceleration and retardation of development as suggested by Messrs. Cope * and Hyatt,† involving a more or less sudden formation of generic forms, than by the theory of Natural Selection, which involves an indefinite number of slight modifications for the production of even a variety, and such a succession of intermediate generic forms as we do not perhaps find recent or fossil.

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3. On the Young of Orthagoriscus mola. By F. W. Putnam, of Salem, Mass.

(Abstract.)

The investigations of which the following abstract gives the general results were undertaken in consequence of the statement, made by Messrs. Lütken and Steenstrup, ‡ that the young of Orthagoriscus differed greatly from the adult, and that Molacanthus was not a distinct genus, but simply the young state of Orthagoriscus. This statement of the distinguished Copenhagen zoölogists led him to believe that they had not seen the young of Orthagoriscus, and had been misled by the singular form of Molacanthus in considering that genus as the younger state of the sunfish. He exhibited drawings of Molacanthus, of the adult form of *Orthagoriscus mola* and *O. oblongus*, and of the young of the last two. The drawing of the young of *O. oblongus* was copied from Harting's work. Harting had figured the specimen in connection with remarks to the effect that he thought the young of this genus were not so different from the adult in form as supposed by Lütken and Steenstrup.

The drawings of the young of *O. mola* were from specimens taken in Massachusetts Bay, and now in the Peabody Academy of Science, having been received from the Essex Institute, in whose

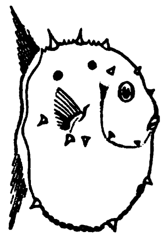
* Origin of Genera. Philadelphia, 1868.

† Parallelism between the Order and Individual in the Tetrabranchiate Cephalopods. Memoirs of the Boston Society of Natural History, 1866, and "American Naturalist," vol. iv., pp. 230, 419.

‡ Œfversigt Danske Vidensk. Selsk. Forhandl., 1863, p. 36.

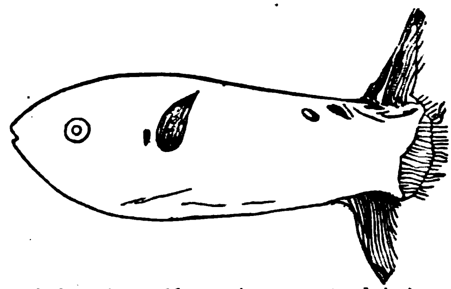
collection they had been for many years. These specimens, four in number, were about two inches in length, and while differing from the adult in several particulars were yet so near to the adult form in all their important features that no doubt could be enter-

Fig. 1.



Molacanthus Palassii (half-grown, natural size).

Fig. 2.



Orthagoriscus oblongus (young, natural size).

tained as to their being the young of *O. mola.* In these young specimens the eye is proportionally very large, and is placed at the margin of the head, while in the adult it is situated some distance

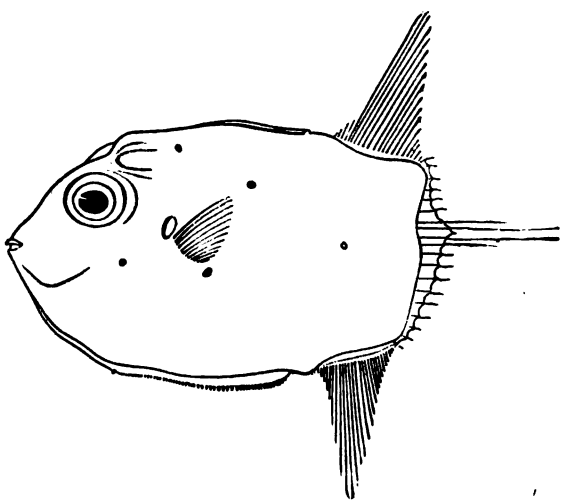


Fig. 3.— Orthagoriscus mola (young, natural size).

from the margin. In the young the dorsal fin and the upper portion of the caudal are thrown respectively a little backward of the anal fin and the lower part of the caudal. By following out a series of drawings, taken from specimens of various sizes, he showed how the growth of these fishes was more rapid in their

dorsal and anterior parts than in other portions of the body; and that from the pushing forward of the posterior parts, and the tendency to develop a large head at the expense of the body, which culminated in the formation of the projecting "nose," so characteristic of the old specimens, he was led to the conclusion that the various forms of the short sunfishes were probably of one species, and those of the oblong type of another; these two forms

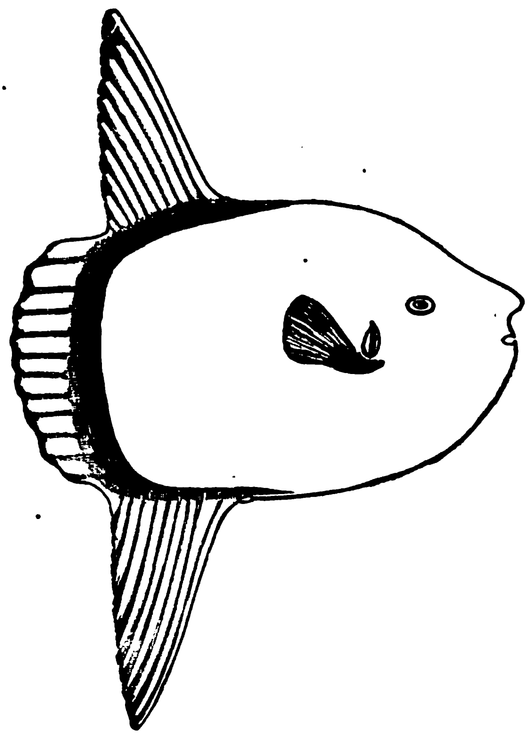


Fig. 4. — Orthagoriscus mola (adult, greatly reduced).

representing two distinct genera of one species each (perhaps two of the *mola* type).

In the young *O. mola* the caudal fin is composed of eight rays in its upper half, and eleven rays in its lower half. These rays are elongated filaments, and by their regular increase in length as they approached the centre of the fin the caudal became a pointed fin. Along the ventral portion of these young fishes is a fleshy ridge, easily detached from the body, and armed with several rows of

small spines. The back, for about half the distance in front of the dorsal fin, has a slightly raised fleshy ridge.

Several interesting points were mentioned in connection with the skeleton of the young, and the changes which take place in its growth. The neural spines of the fifth to the fifteenth vertebræ are closely packed together with the interneural spines, and extending backwards support the dorsal fin; while the hæmal spines of the tenth to the sixteenth vertebræ are in close connection with the expanded interhæmal spines supporting the anal fin. The sixteenth vertebra gives off large neural and hæmal spines, the former having five interneural spines anchylosed with it as in the adult; while the hæmal spine supports nine interhæmal spines, the lower one of which belongs to the anal fin, while the others are of the caudal chain. In the adult only seven interhæmal spines are connected with this hæmal spine. The seventeenth vertebra in the adult lies in the caudal chain of interspinous bones, and, from its being separated from the vertebral column, has been as often considered as an interspinous bone as a vertebra. In the young specimens this vertebra, though separated from the column as in the adult, has in close connection with it two bones above and two below, probably indicating that this vertebra is in reality the consolidation of two vertebral bodies, the seventeenth and eighteenth; while two other small (neural and hæmal) bones posterior to this free vertebra indicate that a nineteenth vertebra existed at an earlier stage. These six neural and hæmal (three each) bones disappear in the adult, and with them the central rays of the caudal fin; and they and the seventeenth, eighteenth, and nineteenth vertebræ are only represented by the free or "floating" seventeenth vertebra which lies in the chain of interspinous bones of the caudal. This is the only instance of a vertebra existing as distinctly separated from the vertebral column known to the author.

A dissection of the soft parts of the young shows the same arrangement as in the adult; the large liver extending in two lobes and enclosing the stomach and portions of the intestine, and the long intestine with its five or six folds. The arrangement of the bundles of muscles is the same as in the adult.

On comparing these young with Molacanthus an entirely different structure is observed. First, the external form of Molacanthus differs greatly from Orthagoriscus; the body is deeper than long in Molacanthus, while the reverse is the case in Orthagoriscus. There

are many largely developed spines on the former, and the skin is thin, silvery, and smooth between the spines. In the latter, the skin is thick; the anterior portion is protected by small granulations, and the rest is covered with fine villous scales; there are five singular naked spaces on each side, three of which have a raised granulated margin, and there is a similar raised space just in front of the dorsal fin. In Orthagoriscus, the dorsal and anal are closely connected with the caudal, which, in comparison with the adult, is largely developed in the young; while in Molacanthus no caudal fin can be traced, and the dorsal and anal are separated by a naked space (though all the figures of this fish, thus far published, represent the dorsal and anal as united by a caudal, the row of small dermal spines at this portion having been mistaken for rays). The skeleton of Molacanthus shows the interspinous bones of the dorsal in connection with the neural spines of the fourth to seventeenth vertebræ, and those of the anal with the hæmal spines of the tenth to seventeenth vertebræ. The vertebral column in Molacanthus terminates abruptly with the seventeenth vertebra, and no caudal chain of interspinous bones can be traced. The liver is small, when compared with that of the young Orthagoriscus, and is composed principally of a large right lobe overlying the stomach. The stomach is small, and the intestine is short, making but two turns, like the letter S; while in Orthagoriscus it is long, and has five or six turns, or coils. The arrangement of the muscles and the bones of the head are, in general, about the same as in Orthagoriscus.

Figure 1 is from a specimen of *Molacanthus Palassii*,* natural size. This specimen was taken from the stomach of a dolphin caught in the North Atlantic, and belongs to the Boston Society of Natural History.

Figure 2 is the young of *Orthagoriscus* (*Cephalus*) *oblongus*, copied from Harting's Memoir. This specimen was taken from the stomach of a "Thon," caught in the Atlantic Ocean, and is represented of natural size.

Figure 3 is from one of the young specimens of *Orthagoriscus mola*, taken in Massachusetts Bay. Natural size.

* The synonymy of these fish will be discussed in full in the "Memoirs of the Academy." The names now used are those under which the species are most generally known.

Mr. Putnam's paper will be published in full in a future number of the "Memoirs of the Peabody Academy of Science," with several plates, illustrating more fully the points mentioned in this abstract.

Figure 4 represents the adult form of *Orthagoriscus mola* from a drawing of a specimen taken in Massachusetts Bay in 1856. Length, forty-two inches; width from tip of dorsal to tip of anal, sixty-four inches. This specimen was fully developed, and shows the characteristic "nose" of the older individuals, the backward position of the eye and the position of the fins. None of the published figures of the adult are very correct in their outline. The best is that of Harting, under the name of *Orthagoriscus ozodura*, in the "Transactions of the Academy of Amsterdam for 1868." An intermediate stage between the young and the adult, here figured, is represented by the figures of Bloch, Donovan, and Yarrell.

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4. On the Condors and Humming Birds of the Equatorial Andes. By James Orton, of Poughkeepsie, N. Y.

The Condor has been singularly unfortunate in the hands of the curious and scientific. Fifty years have elapsed since the first specimen reached Europe; yet to day the exaggerated stories of its size and strength are repeated in many of our text-books, and the very latest ornithological work leaves us in doubt as to its relation to the other vultures. No one credits the assertion of the old geographer, Marco Paulo, that the Condor can lift an elephant from the ground high enough to kill it by the fall; nor the story of a traveller, so late as 1830, who declared that a Condor of moderate size, just killed, was lying before him, a single quill-feather of which was twenty good paces long! Yet the statement continues to be published, that the ordinary expanse of a full-grown specimen is from twelve to twenty feet; whereas it is very doubtful if it ever exceeds, or even equals, twelve feet. A full-grown male from the most celebrated locality on the Andes, now in Vassar College, has a stretch of nine feet. Humboldt never found one to measure over nine feet; and the largest specimen seen by Darwin was eight and a half feet from tip to tip. An old male in the Zoölogical Gardens of London measures eleven feet. Von Tschudi says he found one with a spread of fourteen feet two inches; but he invalidates his testimony by the subsequent state-

ment that the full-grown Condor measures from twelve to thirteen feet.

The old names of *Vultur gryphus*, *V. magellanicus*, *Gypagus gryffus*, and *Zopilotes*, are obsolete, and *Sarcoramphus gryphus* is universally adopted. But it is not yet settled that it is generically distinct from the other great vultures. Thus Sclater and Gurney put the Condor alone in Sarcoramphus; while Gray and Strickland include the King Vulture; and Vieillot and others add a third, — the California Vulture. The structure and habits of the Condor, in our judgment, make it worthy to stand by itself. The King Vulture belongs more especially to the plains; while the California species has straggling feathers on its head, builds nests in trees where it perches, and its time of incubation is only one month.

But a more important question, perhaps, is whether there is but one species. Associated with the Great Condor is a smaller vulture, having brown or ash-colored plumage instead of black and white, a beak wholly black instead of black at the base and white at the tip, and no caruncle. It inhabits the high altitudes, and is rather common. This was formerly thought to be a distinct species, but lately ornithologists have pronounced it the young of the *Sarcoramphus gryphus*. We wish this decision to be reconsidered, for there is some ground for the belief that the first impression is correct; that the "Condorpardo" (as the brown kind is called by the natives) is specifically distinct from the greater "Condor negro." They are always spoken of as separate kinds at Quito, where certainly it would be known if one were the young of the other.

Mr. John Smith, an Englishman of intelligence and acute observation, and a resident of nearly twelve years on the slope of Antisana, where both kinds abound, said to us: "I have heard it said that the Brown Condor is the young of the Black. It cannot possibly be, for I have seen young Condors with white beaks and a few white feathers in their wings. I have also seen old Condors with carbuncles on the head (which are said to come from age alone), and black beaks, and the body brown or ash-colored all over." Bonaparte, in his "American Ornithology," gives a careful drawing of a young male, with a crest, and with white patches on its wings, — both features wanting in the Brown. Lieutenant Gilliss declares, as the result of his observations on the Chilian Andes, that the brown kind is a different species. Further proof

is wanted; but it is quite probable that another species must be added to the genus Sarcoramphus.

The ordinary habitat of the Royal Condor is between the altitudes of 10,000 and 16,000 feet. The largest seem to make their home around the volcano of Cayambi, which stands exactly on the equator. In the rainy season they frequently descend to the coast, where they may be seen roosting on trees; on the mountains they very rarely perch (for which their feet are poorly fitted), but stand on rocks. They are most commonly seen around vertical cliffs, where their nests are, and where cattle are most likely to fall. Great numbers frequent Antisana, where there is a great cattle estate. Flocks are never seen except around a large carcass. It is often seen singly, soaring at a great height in vast circles. Its flight is slow and majestic. Its head is constantly in motion as if in search of food below; its mouth is kept open, and its tail spread. To rise from the ground, it must needs run for some distance, then it flaps its wings three or four times and ascends at a low angle till it reaches a considerable elevation, when it seems to make a few leisurely strokes, as if to ease its wings, after which it literally sails upon the air. In walking, the wings trail on the ground, and the head takes a crouching position. It has a very awkward, almost painful gait. From its inability to rise without running, a narrow pen is sufficient to imprison it. Though a carrion bird, it breathes the purest air, spending much of its time soaring three miles above the sea. Humboldt saw one fly over Chimborazo. We have seen them sailing at least a thousand feet above the crater of Pichincha.*

Its gormandizing power has hardly been overstated. We have known a single Condor, not of the largest size, to make way in one week with a calf, a sheep, and a dog. It prefers carrion, but will sometimes attack live sheep, deer, dogs, etc. The eye and tongue are favorite parts, and first devoured; next the intestines. We never heard of one authenticated case of its carrying off children, nor of its attacking adults except in defence of its eggs. Von Tschudi says it cannot carry, when flying, a weight of over ten pounds. In captivity, it will eat every thing except pork and cooked meat. When full fed, it is exceedingly stupid, and may be caught by the hand; but at other times it is a match for the stoutest man. It passes the greater part of the day sleeping, more

* One of the peaks of Pichincha is called in the Inca language *cuntur guachana*, or "Condor's nest."

often searching for prey morning and evening than at noon,— very likely because objects are then more distinctly seen.

It is seldom shot (though it is not invulnerable as once thought), but is generally trapped or lassoed. Prescott, in his "Conquest of Peru," vol. i. p. 384, speaks of "the great bird of the Andes,— the loathsome condor, who, sailing high above the clouds, followed with *doleful cries* in the track of the army." But the only noise it makes is a hiss like that of a goose. The usual trachial muscles are wanting.

It lays two white eggs, three or four inches long, on an inaccessible ledge. It makes no nest proper, but places a few sticks around the eggs. By no amount of bribery could we tempt an Indian to search for Condors' eggs; and Mr. Smith, who had hunted many years in the Valley of Quito, was never able to get sight of an egg. Incubation occupies about seven weeks, ending April or May.* The young are scarcely covered with a dirty white down, and they are not able to fly till nearly two years. D'Orbigny says they take the wing in about a month and a half after being hatched; a manifest error. They are as downy as goslings until they nearly equal in size a full-grown bird. Darwin was told they could not fly for a whole year. The white frill at the base of the neck, and the white feathers in the wings, do not appear until the second plumage, or until after the first general moulting, during which time they lie in the caves, and are fed by their elders for at least six months. Previous to this the frill is of a deep gray color (Gilliss says "light blue-black"), and the wing-feathers brown.

The head, neck, and front of the breast are bare, indicative of its propensity to feed on carrion. The head is elongated, and much flattened above. The neck is of unusual size, and in the male the skin lies in folds. The nostrils are oval and longitudinal, but in the male they are not so much exposed as in the other sex, since the caruncle forms an arch over them. The olfactories, however, seem to be well developed. Yet the Condor, though it has neither the smelling powers of the dog (as proved by Darwin), nor the bright eye of the eagle, somehow distinguishes a carcass afar off. The color of the eye is variously given: by Latham, as nut-brown; by Cassell, as purple, and by Bonaparte, as olive-gray; but Gurney, in his "Raptorial Birds in the Norwich Museum," states it correctly as pale-brown in the male, and carbuncle-red in the

* In Patagonia, according to Darwin, much earlier, or about February.

female, — a singular difference between the sexes. In young birds the color is dark-brown, which changes with change of plumage. They are peculiarly elongated, not sunken in the head as the eagle's, and very far back, being an inch and a half behind the gape, while those of the eagle are directly over it. The bill is shorter and weaker than the eagle's, and the decurved tip of the upper mandible only one-third as long. The tongue is canaliculate, with serrated edges, which obviously assists in deglutition, as the head is never raised to swallow food. The caruncle and wottle are wanting in the female. The downy ruff is more prominent in the male, but in neither sex completes a circle. The primaries are black, the third and fourth being equal and longest, — a feature wanting in the Old World vultures. The secondaries are exteriorly edged with white. The tail is of twelve feathers, black and even. Legs feathered to the tarsus. Toes united by a small membrane; the middle one is excessively long; the third one comparatively undeveloped, by which the foot is rendered less prehensile than that of other Raptores. Claws blunt, as might be expected from its habit of standing on the rocks; nor are sharp talons wanted, as it seldom seizes living prey. The nail of the hind toe is more curved than the other three, but far less than the talons of the eagle. The female Condor is smaller than the male, an unusual circumstance in this order, the feminine eagles and hawks being larger than their mates.

Our knowledge of the habits and economy of the Trochilidæ is very meagre. The relationship between the genera is not clear, and one species is no more typical than another. The only well-marked divisions we can discover are those adopted by Gould and Gray, — the Phæthornithinæ and Polytminæ. The former, popularly called "Hermits," are dull colored, and frequent the dense forests. They are more numerous on the Amazon than the other group; and I know of no specimen from the Quito Valley, or from any altitude above 10,000 feet. They usually build long purse-like nests of vegetable fibres, covered with lichens and lined with silk cotton, and hung from the extremities of leaves over watercourses.

The Polytminæ comprise the vast majority of the Humming Birds, or nearly nine-tenths. They delight in sunshine, and the males generally are remarkable for their brilliant plumage. The diversified slope of the Andes are more favorable for their development than the uniform plains. Their headquarters seem to be in

New Grenada; but the precise distribution of the species is not so well known as it might be. Near the equator the species are nearly stationary; some, as the *Oreotrochilus*, are confined to particular volcanoes, or an area of a few square miles. There is, therefore, greater need of determining the precise locality of a specimen; yet, in the best monograph on the Trochilidæ (Mr. Gould's), species are assigned to such indefinite regions as Ecuador, Peru, etc. But Ecuador ascends from the sea coast to 20,000 feet, and is traversed by two Cordilleras and a plateau, making three very distinct districts; the faunæ of the west slope, the Quito Valley, and the Napo Country, being, with less than half a dozen exceptions, entirely separate. Of the four hundred and thirty known species of Hummers, twenty-seven are found in and around the Valley of Quito, thirty-seven on the Pacific slope, and twenty on the oriental side of the Andes, — making a total of eighty-four, or about one-fifth of the family, within the Republic of Ecuador. The paucity of Hummers south of the equator, in comparison with the number on or just above the line, has been accounted for by the fact that the dry and sterile plains of Peru and the barren pampas of La Plata are unsuited to insect, and therefore to Humming Bird, life. This cannot be the whole reason; for there are myriads more of insects on the Lower Amazon than on the Andes, yet there are not fifteen species east of Egas, or the last 1,500 miles. If the wanton destruction of Humming Birds for mere decorative purposes continues for the next decade as it has during the last, several genera may become utterly extinct. This is evident when we consider that many a genus is represented by a single species, which species has a very circumscribed habitat, and multiplies slowly, producing but two eggs a year; and that at Nanegal, *e. g.*, a famous locality near Quito, it was possible ten years ago to shoot sixteen or eighteen per day, while now it is hard to get half a dozen.

Nidification is uniform at the same altitude and latitude. In the Valley of Quito it occurs at about the close of the rainy season, or April. The nest is built in six days, but one egg is laid before the nest is finished. The usual height of the nest above the ground is six feet. Some, like that of our northern species, are cup-shaped and placed in the fork of a branch; others are hung like a hammock by threads or spiders' webs to trees or rocks; while the long-tailed *Lesbia* constructs a purse-shaped nest resembling those of the Phæthornithinæ on the Amazon. Like the "hermit" Hum-

mers of the lowlands, the Purple-eared (*Petasophora iolata*) alone of the Quito species hangs its nest over a stream of water. As to the materials of the nest, I have noticed a fact which I cannot explain: our northern Hummer glues lichens all over the outside; so do a number of species in Brazil, Guiana, etc.; but in the Valley of Quito, moss is invariably used; not a particle of lichen have we seen on any nest, though lichens abound.* Mr. Gould mentions a nest which, being heavier on one side than the other, was weighted with a small stone to preserve the equilibrium. A few Hummers, as the *Glaucis* of the lowlands, lay but a single egg; but the usual number is two, and they are always of a pinkish hue when freshly laid. The spotted egg of a species on the Upper Amazon, noticed by Edwards, has not been seen by other observers. The time of incubation at Quito is twelve days, varying a day more or less according to the weather. There is but one brood a year, as with *T. colubris*, in our Northern States. But in our Southern States, and in Brazil, there are generally two. Drapiez says "sometimes four broods," but we conjecture that this is a mistake.

No insessorial bird seeks its food at so great an elevation as the *Oreotrochilus*.† This has been seen clinging to the volcanic cliffs of Chimborazo; but no other Hummer has been observed to alight on the ground, for which, in fact, their sharp, hooked nails are ill fitted. Of the sixteen genera represented in the Valley of Quito, the average length of the bill is three-fourths of an inch; and the most numerous plants are the Compositæ, Scrophulariaceæ, and Labiatæ. The curved-billed *Eutoxeres* is usually seen around the fuschias or the scales of the palms, seeking for spiders. The *Oreotrochilus* feeds its young by bringing them flowers of the myrtle; then throwing them away, it goes for more. As Bates has said, Hummers "do not proceed in that methodical manner which bees follow, taking the flowers *seriatim*, but skip about from one part of the tree to another in the most capricious way." No other vertebrate has a tubular tongue, an organ adapted for gathering both insects and honey. ‡ No other family of birds contains so many

* A similar variation is seen in the nests of the chimney-swallows: our species (*Chætura pelasgia*) builds of twigs glued together with saliva; while its Quito representative (*C. rutila*) builds of mud and moss.

† We have seen flies on Pichincha at the height of nearly 16,000 feet.

‡ Dr. Crisp contends that the bifid portion of the tongue is not hollow, but is composed of solid cartilaginous material. The same anatomist also asserts, in opposition to the opinion of Professor Owen, that the bones of the Hummer, like those of the swallow, do not contain air.

species; nor has any other group such varied forms of bill, — compare the short bill of the *Ramphomicron*, one-third of an inch, and the six-inch bill of the *Docimastes;* the bill of the *Eutoxeres*, bent downward into a semicircle, and that of the *Avocettula*, turning upwards. To an unequalled splendor of plumage, — resembling laminæ of topaz and emerald, — Nature has not added the gift of song. Its ordinary cry is a shrill *chirik*, uttered by the males in their petty quarrels. The "warbles" ascribed to the *Mellisuga* and *Oreotrochilus* need to be heard again to be credited.

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5. On the Relations of the Orders of Mammals. By Theodore Gill, of Washington, D. C.

(Abstract.)

In order to render at once appreciable the course which I have followed in my studies, I would enunciate the guiding principles by which I have been influenced. These were five: —

1st, Morphology is the only safe guide to the natural classification of organized beings; teleology, or physiological adaptation, the most unsafe and conducing to the most unnatural approximations.

2d, The affinities of such organisms are only determinable by the sum of their agreements in morphological characteristics, and not by the modifications of any single organ.

3d, The animals and plants of the present epoch are the derivatives, with modification of antecedent forms to an unlimited extent.

4th, An arrangement of organized beings in any single series is, therefore, impossible; and the system of sequences adopted by genealogists may be applied to the sequence of the groups of natural objects.

5th, In the appreciations of the value of groups, the founder of modern taxonomy (Linnæus) must be followed, subject to such deviations as our increased knowledge of structure necessitates.

The adoption of such principles compels us to reject such systems as are based solely on modifications of the brain, those of the placenta, and those of the organs of progression, such modifica-

tions not being coincident with corresponding modifications of other organs, and therefore not the expressions of the sum of agreements in structure.

Commencing with the highest forms of Mammals, we have, by universal consent, the Primates. This Linnæan order, purged of the Chiroptera referred to it by its founder, includes man, the monkeys, and the lemurs, with their respective allies. It is divisible into two suborders, the Anthropoidea and the Lemuroidea.

The subjects of the next highest group are not so universally recognized; but the Feræ, or Carnivora, on account of the nature of the skeleton, the development of the brain, and the organs for the perpetuation of their kind, seem to be most entitled to that rank. This order seems to embrace as suborders the ordinary gressorial Carnivora (Fissipedia) and the Pinnipedia, or Seals, Walrus, etc.

An extinct type — the Zeuglodontes — is related on the one hand to the Seals, and on the other to the toothed Cetaceans. The relation with the latter is, however, the most intimate; and it may be combined with them and the whale-bone whales into one order, — the Cete, — of which each form represents a suborder. The relations of the order with the Feræ is only masked by the extreme teleological modifications.

As derivatives from the same primitive stem as the Feræ, the Insectivora may be placed next in order. The affinity of the Chiroptera to that order is now universally recognized, notwithstanding the extreme teleological modification of its anterior members. The Ungulata are probably the derivatives from the same common stock as the Feræ; the development of the brain, organs of generation, etc., indicate their comparatively high rank. Next may be placed the Glires or Rodents, and, last of the Placental Mammals, the Edentata, the structure of the skeleton and especially of the skull, the organs of generation, etc., appearing to indicate, with sufficient distinctness, that thus degraded are their rank.

The relations of the subclass Didelphia with its single order Marsupialia, and of the subclass Ornithodelphia with another unique order, Monotremata, are now recognized beyond dispute.

Resuming now the consideration of the sequence by linear series, we may approach, by normally specialized forms, the more generalized of each series; and thence, in such cases as are necessary, diverge in another direction to the abnormally specialized.

We would then have something like the series thus represented on the blackboard (some suborders being omitted), the index hands representing the respective nature and direction of the groups.

SUBCLASS MONODELPHIA.

I.—PRIMATE SERIES.

Order Primates.

Suborder *Anthropoidea*. Suborder *Lemuroidea*.

II.—FERAL SERIES.

Order Feræ.

Suborder *Fissipedia*. ☚ ☛ Suborder *Pinnipedia*.

Order Cete.

Suborder *Zeuglodontes*. Suborder *Odontocete*. Suborder *Mysticete*.

III.—INSECTIVOROUS SERIES.

Order Insectivora. ☚ ☛ Order Chiroptera.

IV.—UNGULATE SERIES.

Order Ungulata.

Suborder *Artiodactyla*. Suborder *Perissodactyla*.

Order Hyracoidea. ☚ Order Proboscidea. ☛ Order Sirenia.

V.—RODENT SERIES.

Order Glires.

Suborder *Simplicidentata*. Suborder *Duplicidentata*.

VI.—EDENTATE SERIES.

Order Bruta, or Edentata.

SUBCLASS DIDELPHIA.

Order Marsupialia.

SUBCLASS ORNITHODELPHIA.

Order Monotremata.

Any orders than those admitted seem problematical, and the adoption of an order Bimana for man alone—much more a subclass—seems to be opposed by every sound principle of Taxonomy. There is scarcely a proposition in biology more demon-

strable than that man is the derivative from the same immediate stock as the higher anthropoid apes, and probably after the culmination to nearly the same extent as at present of the differentiation of the order into families and subordinate groups.

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6. On the Early Stages of Discina. By Edward S. Morse, of Salem, Mass.

(Abstract).

Referring to his communication of last year on the "Early Stages of Terebratulina," and the evidences then adduced of the proofs of the close relations existing between the Brachiopoda and the Polyzoa, he said that an examination of the early stages of Discina showed the same simple lophophore, sustaining a few cirri, the stomach hanging below, and other features in which a resemblance was seen.

The perivisceral wall is made up of two layers of muscular fibres, which cross each other, giving the wall a reticulated appearance.

While the young shell has an elliptical outline, there is marked out a perfectly circular area, indicating that at the outset the embryo possesses a circular plate above and below. The muscles were very large, and occupied a greater portion of the perivisceral cavity. The setæ fringing the mantle were very long, those projecting from the anterior margin being three times the length of the shell.

These setæ were lined with setellæ.

The mantle margin, the blood lacunæ, and the bundles of muscular fibres to move the setæ were all described.

He was indebted to Professor A. E. Verrill for the specimens examined.

7. On the Organization of Lingula and Discina. By Edward S. Morse, of Salem, Mass.

As many of the facts were referred to more particularly in his communication on the "Brachiopoda as a Division of the Annelida," the author would only record some of the more prominent points brought out under this head. He confirmed Carl Semper's view regarding the circulation of Lingula; viz., that by ciliary motion. The perivisceral cavity appeared to be in direct communication with the lacunæ of the mantle and with the cavity of the peduncle. The circulation was voluminous and rapid: no trace of pulsation could be detected. The fluid was not blood proper, but chyle-aqueous; and distinct from this was found the little vessel upon the dorsal surface of the intestine, as pointed out by Hancock, and called by him the heart.

From repeated examination of the oviducts, he could state positively regarding the nature of these organs. The internal mouth was plaited and turned towards the sides; the remaining portion of the oviduct was reddish in color, and glandular, and probably performed a renal function as in similar organs among the annelids.

The sexes were separate. The coiled arms had a limited power of motion. The coils could be raised or depressed, and the axis of the coil could be at right angles to the longitudinal axis of the body or parallel to it.

The contents of the stomach were found in all the lobules of the liver, indicating that the food circulated in these hepatic prolongations, as in the annelids. Upon young Lingula a perfectly circular area could be seen near the beak of the shell: this indicated the form of the embryo shell, and coincided with that of Discina. The movements of living *Lingula pyramidata*, upon which these observations were made, were described. As they live in the sand upright, their peduncle encased in a sand tube, it was interesting to notice a modification in their habits when confined in a bowl. In a short time after confinement, they had built new tubes, which adhered to the bottom of the bowl through their whole length. They would extend from these tubes, or withdraw when alarmed. All of the specimens he had brought from North Carolina in May were alive at this date, August 19th. They had been confined in a small bowl, with a little sand, and the water changed every two or three days. This vitality was suggestive, since Lingula had existed from the earliest geological ages to the present time.

A live specimen was exhibited to the members, with the statement that he had carried all his living specimens to Eastport, Me., and they had there been subjected to the chilling waters of that region; that the specimen he had with him had been brought in a little jar containing sea water; and that a bottle of sea water had been brought to Troy, so that the water could be changed.

In describing Discina, he mentioned in detail the muscular, alimentary, circulatory, and reproductive systems. The oviducts were very conspicuous, and had broad, trumpet-shaped mouths. The arteries of Hancock he believed to be nerves, as Professor Owen first described them to be. He found them arranged precisely as in Lingula, and in Discina had traced them to their termination in the posterior occlusor muscles.

Dr. Gratiolet had also been led to the same conclusions regarding the nature of these supposed arteries, from a careful study of a species of Lingula.

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8. The Brachiopoda, a Division of Annelida. By Edward S. Morse, of Salem, Mass.

Reference was first made to the branch of Mollusca, as it was understood forty years ago, when, misled by external characters, many worms, like Serpula and Spirorbis, and a group of Crustaceans, the Cirripedia, were included with Mollusks, and yet from a proper recognition of their characters these diverse forms had been eliminated from time to time, and referred to their proper branches. After long and careful study, Mr. Morse was prepared to state that the Brachiopods were true Articulates, and not Mollusks, and that their proper place was among the worms, forming a group near the tubicolous Annelids.

He stated that for the past year he had been deeply engaged in the study of the Brachiopoda, and more particularly their early stages. Beside material from the coast of New England, he had had, through the kindness of Professor A. E. Verrill, a large lot of Discina from Callao, Peru, belonging to the Yale College Museum. From these he had studied their early stages, but, as he had in preparation a memoir upon the subject, he would now confine himself to the considerations that follow.

He first spoke of the structure and composition of the Brachiopod shell, and pointed out the relations between the cœcal prolongations of the mantle in Terebratula and a similar structure in the skin of the worms. He had submitted the shell of Discina to chemical tests, and believed it to be chitinous. Gratiolet had already given the chemical analysis of *Lingula anatina*, and found forty-two per cent of phosphate of lime, and only six per cent of carbonate of lime. The position of the valves of all Brachiopoda were dorsal and ventral, and this was a strong articulate character to be compared to the dorsal and ventral plates of the Articulates. The horny setæ that fringe the mantle of Brachiopods was a feature entirely absent in the Mollusca, and peculiar to the worms.

The bristles of worms differ from those of other articulate animals in having sheaths containing muscular fibre, while in other Articulates the hairs were simply tubular prolongations of the epidermal layer. In Brachiopods the setæ, or bristles, were secreted by follicles, imbedded or surrounded by muscular fibres, and were moved freely by the animal. In the structure of the setæ, he found an identity with that of the worms. He then called attention to the resemblance between the lophophore of the Brachiopods and a similar structure in the tubicolous worms. In Sabella the cephalic collar was split laterally, and a portion of it reflected. Let this collar be developed so as to cover the fringed arms, and a representation of the mantle of Brachiopoda would be attained. The thin and muscular visceral walls suggest similar parts in the worms. The circulating system he had not sufficiently studied, though Dr. Gratiolet had stated that in this respect there was a strong resemblance to the Crustacea.

In regard to the respiratory system, Burmeister had shown that there was a resemblance between the soft folds, or lamellæ, developed on the internal surface of the mantle of Balanidæ, and similar features in Lingula; though the existence of these folds in Lingula had been questioned, he would presently show that Vogt was right in his observations. In regard to the reproductive system, he called attention to the fact that in one group of Cirripeds the ovaries were lodged in the upper surface of the peduncle, while in another group the same parts were lodged in the mantle. A similar condition existed in the Brachiopods, where in one group the mantle holds the ovaries, while in another group they are found in the visceral cavity.

Through Polyzoa also he showed that, in their winter eggs or statoblasts, a relation was seen to the ephippia of Daphniæ, and the winter eggs of Rotifers.

Of great importance also, and upon which he laid particular weight, were the peculiar oviducts with their trumpet-shaped openings so unlike the oviducts of Mollusks, and, as he believed, bearing the closest affinity to the oviducts in many of the worms; namely, a pair of tubes, and in one case two pairs, having their inner apertures with flaring mouths, suspended in the visceral cavity, thus opening a direct communication between the visceral fluids and the surrounding media. He then called attention to what little information we had regarding the embryology of the Brachiopods. Lacaze-Duthiers had shown that in Thecidium the embryo was composed of four segments with eye-spots and other strong articulate features. Fritz Müller had given a description, with figures, of the early stage of Discina, in which we have not only little cirri projecting from the shell, but a little appendage recalling the plug or operculum in some of the tubicolous worms.

Of great importance also was the fact that, in the early stage of Discina, Müller observed large bristles, and these were moved freely by the animal. Smitt had shown that in certain Polyzoa (Lepralia) the embryo, besides being furnished with cilia, also supported several bristles, or setæ, which were locomotive; and finally, in the worms, Claparède and Mecznikow had figured an embryo of Nerine in which barbed bristles were also developed. Mr. Morse referred to his communication before the American Association for the Advancement of Science on the "Early Stages of the Brachiopods," in which he had shown the intimate connections existing between this group and the Polyzoa. Now Leuckart had already seen reasons for placing the Polyzoa with the Annelids; and he would call attention to *Crepina gracilis* and *Phoronis hippocrepia*, admitted to be worms, or early stages of them, and their close resemblance in nearly every point of their structure to the hippocrepian Polyzoa. Mr. Morse then stated that, in the evidence already given, he had drawn his conclusions from alcoholic specimens of Terebratula and Discina, and from the papers of Lacaze-Duthiers, Claparède, Mecznikow, Hancock, Huxley, Vogt, Hyatt, Williams, De Morgan, and others. He felt the importance of first examining Lingula in a living condition before making these announcements; and for this reason he had recently visited the coast of North Carolina for the express purpose of finding, if possible,

the rare *Lingula pyramidata* of Stimpson, first discovered by Professor Agassiz in South Carolina. After nearly a week's fruitless search he had found it, had studied it alive, and had brought with him living examples, which he has the pleasure of exhibiting before the Association.

He would here express his deep sense of gratitude to Dr. Elliott Coues, Surgeon U. S. A., at Fort Macon, N. C., and the Commandant of the Post, Major Joseph Stewart, U. S. A., for the constant aid and sympathy rendered to Dr. A. S. Packard and himself during their visit there. He would not enter into a description of Lingula, as he had already in preparation a memoir upon the subject, but would call attention simply to the additional evidence in support of the views advanced.

Lingula was found in a sand shoal at low-water mark, buried just below the surface of the sand. The peduncle was six times the length of the shell, and was encased in a sand tube differing in no respect from the sand tubes of neighboring annelids. In many instances the peduncle was broken in sifting them from the sand, yet the wound was quickly repaired, and another sand case was formed.

He observed that Lingula had the power of moving over the sand by the sliding motion of the two valves, using at the same time the fringes of setæ which swung promptly back and forth like a galley of oars, leaving a peculiar track in the sand. In the motion of the setæ he noticed the impulse commencing from behind, and running forward.

Within the mantle he found a series of rows of prominent lamellæ in which the blood rapidly circulated, thus confirming the correctness of Vogt's observations. These lamellæ were contractile, however.

The peduncle was hollow, and the blood could be seen coursing back and forth in its channel. It was distinctly and regularly constricted or ringed, and presented a remarkably worm-like appearance. It had layers of circular and longitudinal muscular fibre, and coiled itself in numerous folds, or unwound at full length. It was contractile also, and would quickly jerk the body beneath the sand. But the most startling observation in connection with this interesting animal was the fact that its blood was red. This was strongly marked in the gills and various ramifications of the mantle, and in the peduncle. At times the peduncle would become congested, and then a deep rose blush was markedly distinct. Mr.

Morse expressed his gratification in having come to the conclusions in regard to the annelidan characters of Brachiopods a long time previous to his observations on Lingula.

He then concluded by stating that the Brachiopods should be removed from the Mollusca, and placed with the Articulates among the Annelids; that the Brachiopods came near the tubicolous worms, though they were much more highly cephalized; that they exhibit certain crustacean characters, but were widely removed from the Mollusca.

It was interesting in this connection to note that Gegenbaur, in the second edition of his "Outlines of Comparative Anatomy," just published, had removed the Polyzoa and Tunicates from the Mollusks, and placed them with the Vermes, and that many other European naturalists were also demonstrating the worm-like characters of the Polyzoa.

He believed the Brachiopods to be a comprehensive type, exhibiting general articulate features, and forming another example of those groups belonging to the past that exhibit the characters of two or more classes combined.

It was interesting in this connection to remark that Lingula, one of the earliest forms created, had yet remained the same through all ages of the earth's history.

III. BOTANY.

1. The Law of Fasciation, and its Relation to Sex in Plants. By Thomas Meehan, of Germantown, Penn.

At the last meeting of the Association Dr. Sterry Hunt handed me a fasciated branch of *Picea balsamea*, in which the branchlets of the fascicle presented a very distinct appearance from the normal form. In the language of the person who directed Dr. Hunt's attention to it, "it seemed as if a Norway spruce was being developed from the Balsam Fir." From facts I had previously observed and embodied in my paper on "Adnation in Coniferæ," read at Chicago, it was clear that these branchlets did not possess the adnating power which I showed in that paper to be characteristic of the highest

vigor. The leaves were not distichous, but scattered around the weak stems, terete, and in every respect like those on plants in the young seedling state; and corresponding in this character with the free leaves in arbor-vitæ, juniper, and similar plants, when the branches are forced to grow in shady places, or under other conditions unfavorable to perfect nutrition. I was astonished at the suggestion that fasciation could possibly be a weakness of development, because, though very little has been written about this phenomenon, all that I have read refers to over-nutrition as the probable cause. I believe I can now offer some facts which will show that there are two distinct causes of fasciation, — one an abundant supply of nutrition, which consolidates together parts normally free, as we often see in asparagus, plantains, dandelions, and other common things; the other a weakened flow of vitality, which is not able to combine parts together which usually go to make up the integrate structure, and which take the form known amongst the people generally as "crow's nest branches."

That the last cause was probable in the case before me I saw, as I have already stated. I found several specimens on living trees of Balsam Firs near me, similar to the one given to me by Dr. Hunt, and watched them frequently. That they were weak developments was clear from the fact that they made little more than an inch of growth every year; that the leaves, usually of a dark green, were of a paler hue; and that they were destroyed by the first frosts of autumn, becoming as deciduous as the larch while the regular leaves continued evergreen, and many of the fasciated shoots died during the course of the winter. The pale tint was evidence of defective nutrition, as it is well known to every practical gardener that, when from any cause the fibres of a plant become injured, and the free supply of sap from any cause, as by ringing the bark, is cut off from the leaves, they become of a pale sickly hue. It was also evident, from the inability of the fascicle to keep its leaf green and some of its branchlets alive during winter, that vitality was at a low stage.

I examined the fasciated branches on other kinds of trees, and found these general results in all; but in none so well illustrated as in a sassafras tree, which had nearly all of its branches in this condition, one of which I exhibit. Another tree was alongside of it quite free from this character. The one with the fasciated branches was not nearly so large as the other, although there appeared no reason in soil or other circumstances why it should not be. A

great number of the branchlets in the fascicles also died out every winter.

I was very anxious to find how these fasciated branches would behave in a state of inflorescence, but could not find any case of one bearing flowers. At length I discovered them in the common blackberry (*Rubus villosus*), and was pleased to find that they not only confirmed the view I had taken of the cause of this kind of fasciation, but also furnished, in the most unexpected manner, new facts in favor of my theory of last year respecting sex; namely, that the male is the offspring of a declining vitality. These fasciated branches in Rubus I am inclined to think common, and it will be very easy to verify the following facts: —

In these fasciated branches the number of branchlets varies from five to fifteen. The pale tint characteristic of failing nutrition is particularly marked; while the lower leaves die away earlier than in those branches on the same cane produced in the regular way. That the whole of these leaves will fall first I anticipate, but cannot speak from actual knowledge. Here are perfect evidences of failure of nutrition, decreased vitality, and fasciation all going along together.

Now, in its relation to sex, I pointed out in my paper on this subject, last year, that the flower-bearing parts of plants were weak in proportion as they diverged from the feminine condition. In a polygamous plant, the pistillate flower is on the stoutest axis; the hermaphrodite, the next; the male, the weakest. So also in the grades of masculine weakness. When the male flowers had their stamens reduced to petals, the plant, or axis of the plant, was weaker than before; and when the sepals took on the nature of leaves, or the leaves lost their chlorophyllous character and simulated petals, vitality was well known to horticulturists to be in a weaker state than before.

Here are the same illustrations. As you see, in this specimen, the lower branches, pushing in the usual way, have the regular calyx segments; but, in the upper set of fasciated ones, the segments have taken on a leaf-like form, the stamens have increased in size, and the pistils, as shown by the great number in the flowers which have failed to swell out their ovaries, are proportionately defective. A tendency to masculinity is clearly in connection with defective nutrition, decreased vitality, and fasciation.

I saw this, however, still more clearly demonstrated in a field of a cultivated variety of blackberry, — the Willson's Early, — on the

farm of Mr. Wm. Parry, of Cinnaminson, New Jersey. His son, Charles, an intelligent and observing young man, called my attention to the fact that wherever these fascicles occurred the flowers were nearly double and no fruit followed. I found this to be the case so far as the flowers were concerned. In some there were as many as twenty petals, and the calycine segments were largely foliaceous. There could not be clearer illustrations of masculinity and fasciation going along together.

Returning to fasciations of the "crow's nest" kind, we may then safely say that they are bundles of branches formed from germs, which, if nutrition had been sufficient to provide the required vitality, would have adnated together, and formed one vigorous, united axis, instead of, as now, each struggling on in its own weak way.

I am aware that this conclusion may conflict with received theories as to the formation of axis or stem. It would seem to imply that one perfect branch is but a collection of smaller homogeneous ones. I sometimes see cases which indicate that this may be so. I have here a portion of a cane of *Rubus occidentalis*. At the base it is no thicker than the average of other canes; but near the middle of its length it has separated into four smaller canes. It has been usual to regard these cases as the result of an early and accidental union of several points; but in this case there is no increase in bulk, nothing but clear assumption to warrant any such theory. On the contrary, every appearance suggests, — not that the union of branches is the accident, but that that is the normal condition, and that it is the division into the fasciated branchlets which is the departure from the rule.

I do not, however, wish to ask for this suggestion any thing more than it may be worth. Others more able than I can better interpret the circumstances. The main object I have had in this paper is to show that all the circumstances which accompany fasciation are those connected with a low stage of vitality. On this I think there can be no mistake.

After the reading, Mr. Meehan said, as he had already remarked in the paper, illustrations from flowering specimens of fasciated branches seemed rare. On the excursion to Albany with the Society the day before, he had gathered a specimen of a fasciated branch of *Atriplex rosea*, which species was growing abundantly there. This specimen he exhibited to the meeting, and showed that it confirmed all the points previously adduced from Rubus.

The regular inflorescence of this Atriplex was in the order pointed out in the general law as developed in his paper on sex of last year; that is, the female flowers were situated in the strongest lines of axial vigor, the male flowers occupying the weakest positions on the ends of each branchlet; but in this fasciated Atriplex, all the branchlets were of male flowers only, showing that the fasciation was the result of a weakening influence.

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2. On Objections to Darwin's Theory of Fertilization through Insect Agency. By Thomas Meehan, of Germantown, Penn.

It often occurs that in the enunciation of new theories the authors meet with facts which seem to oppose them, and for a time present insurmountable difficulties. But it not unfrequently happens that these very objections ultimately prove to aid rather than to obstruct the progress of the newly discovered law in popular favor.

Mr. Darwin has shown that in many plants fertilization is carried on by means of insect agency; and he has proved this to be so important a law that, he says, "if the race of Humble Bees were to die out, some species of plants would soon become extinct in Britain."

The objection to this is that some plants appear to have their sexual organs admirably adapted to the use of these insect agencies, and yet the bees seem to studiously avoid using them; and again, often where the structure is the best suited to throw the pollen on the insect which is to carry it away, there is the least inducement for bees to make use of the opportunity.

There is probably no plant which has its organs more beautifully adapted to the work of this insect agency than the Salvia. The anthers are divided on the filaments, and while one part is extended towards the mouth of the corolla, and performs its pollen-bearing functions, the other extends down towards the base of the corolla tube, and assumes a petaloid form. The divided anther is thus balanced on a pivot. The lower petaloid portion so closes the mouth of the corolla tube that any insect thrusting its probos-

cis down it must lift the lever, when the polleniferous portion is brought down on the insect's back. When it attempts to enter another flower, the pistil is usually exserted; and the pollen is thus brought into exact contact with it. In addition to this, there is usually an abundance of sweet liquor at the base of the corolla tube; all things tending, as one would suppose, to make the illustration of insect agency as perfect as possible. But now come the objections. In many Salvias, the petaloid prolongations of the anthers are very poorly developed; and yet many of these abound in the honeyed juice. If the bee enters them, the chance of its having any pollen thrown on its back is comparatively small. At other times the mouth is so completely closed that the slightest touch will cause the pollen to fall, but there is little sweet to invite bees. *S. Egyptica* is an excellent illustration of this. I am aware that the mere reasoner might say that this was a proper arrangement; that with less inducements for the presence of insects, the arrangements for making use of them when they do come should be more perfect. But against all this comes the fact that the bee never enters either class of flowers at all. I have watched by the hour, and never saw an insect enter that was large enough to make the slightest use of all this beautifully contrived arrangement for cross-fertilizing flowers. But the bees get the honey. They bore a small hole near the base and suck the honey through the tube from the outside, without the slightest regard to the theories of Darwin.

I have tried to harmonize these facts with Darwin's, and failing have sometimes thought they should weigh against his results; but his facts were so direct, so conclusive as far as they went, that it was more reasonable to hope something would explain them, rather than that there should be a lasting contradiction. This view was the more reasonable, as it was a fact that these Salvias, which were thus treated by the bees, seldom perfected seeds.

I think I can now harmonize these facts with the theory, by an analogous case with Petunia. Here also the Humble Bees refuse to draw the honey up through the tube. I have seen an occasional one, evidently a greenhorn, attempt it; but after trying three or four, it would fly away from the whole bed full of flowers, in disgust. The more experienced fellows make a slit in the base of the tube, through which they get the honey. By examining Petunia flowers with a lens, these slits can be readily seen, or still better to watch the insect in the very act. Here was another puzzle. A large

bed under my office-window afforded an opportunity to see them every day. No insect that I could ever see assisting fertilization in any way, and the viscid nature of all the parts very much against any self-acting power. It was a worse case than the Salvia, because the Petunia is always highly productive of seeds.

But at length the mystery was explained. Though no insect but the Humble Bee visited the flowers by day, they were thronged by moths at night. These were the insects through whose agency the fertilization of these flowers is carried on.

I have thought that this account of the way the Petunia is fertilized may not only be a novel fact to many here, but convey a very useful lesson applicable to many things, — to theories of my own, as well as to Mr. Darwin's. No doubt the seeming difficulties of the Salvia could be settled as satisfactorily as this of Petunia, if one could be in a position to watch for the facts. Possibly, in the countries where Salvias abound, insects peculiarly adapted to operate on the Darwinian method exist, which choose their own time and way of doing it.

The Petunia, we certainly see, relies on the night moth, and not on the Humble Bee. They use their proboscis to extract the honey, and thus fertilize the other flowers. Here, at least, though at first in opposition, the facts wonderfully confirm Darwin's; and it seems a great point gained in the harmony of apparently conflicting facts.

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3. On Two Classes of Male Flowers in Castanea, and the Influence of Nutrition on Sex. By Thomas Meehan, of Germantown, Penn.

In my paper on the "Laws of Sex in Plants," which I read to the Association last year, I gave some account of a few of the leading facts I had observed, which seemed to indicate that a higher degree of vigor or vital force was necessary to produce the female than the male sex in plants. I have not met with one fact which has suggested any other conclusion; nor have I heard any fact suggested by others which could lead to any other opinion. Wherever there has been any change in the sexual relations, the male flowers or organs are invariably associated with declining vigor; while only

in those parts of plants most favorable to the highest state of vitality are the female flowers most numerous or generally found.

This theory is so capable of easy demonstration by any one who will personally examine the first monœcious tree or plant he meets, that I feel sure nothing further will be needed from me to sustain it. I propose now to go a step further in the endeavor to ascertain the exact laws of nutrition by which we may control these sex-producing forces respectively.

I have here some specimens of *Castanea Americana*, our common sweet chestnut, as my first contribution to this class of facts.

But first I would call attention to the fact that there are two classes of male flowers in this tree. It is scarcely possible that this should have escaped the eyes of other observers, but I find no reference to it in botanical works. One class of male flowers comes out from the axils on half-starved shoots; the other class terminates the strong vigorous shoots which bear the female blossoms. Those of the former class have their flowers set densely on the rachis; on the latter they are somewhat scattered, and do not open until a week or ten days after the latter. The numerous flowers we see on the chestnut-trees are of the former class, and generally have mostly fallen before those associated with the female flower open. I think it likely that one of these classes does not perform the usual fertilizing functions, but could not satisfy myself positively. The interest for us here is to note the antagonism, so to say, between the male and female blossoms. The comparatively weak spikes show that they were formed only after the female flowers had received matter enough for their perfect development. Only the surplus matter goes to form the male flower at the apex. This is better shown by the fact that often there is no prolongation beyond the female flower; no male blossoms. At other times only a few, — never, as we have seen, the number which appears on those spikes which are wholly masculine in their nature.

In regard to the influence of nutrition on sex, the specimen I exhibit is from a tree at least forty feet high and six feet in circumference. It is on my ground; stands out by itself, and has borne fruit regularly, and in good crops annually. This year the leaves are all streaked with yellow, as in this specimen.

Horticulturists well know that this appearance on the leaves of plants arises from an interruption of the nutritive functions. If a branch be partially ringed to produce fruitfulness, or if the roots be

injured in transplanting, or rotted by an over-supply of water, a yellow tint to the foliage is the invariable consequence. In some way, then, this chestnut-tree has, this season, met with some check to its nutritive system, — received a blow to its vitality, which has resulted in this yellow-tinted leaf. The effect of this on the sex is, that, though thousands of male flowers are produced, there is not one female flower, one young chestnut, on the whole tree that I can find.

I think this instance satisfactory, as far as it goes, that defective nutrition is one of the agents which operates on these laws of vitality that govern the sexes.

I am frequently struck with the fact that the tendency of my observations is in opposition to recognized laws of some branch of science related to the circumstance I speak about.

This paper affords a case of this kind. I know that "embryology teaches us that arrest of development shows itself first in the absence of those parts that have arisen latest in the course of evolution; that, if defect of nutrition causes an earlier arrest, parts that are of more ancient origin abort; and that the part alone produced, when the supply of materials fails near the outset, is the primordial part."* But supposing that nature must, of necessity, have given the priority of evolution to the female, or reproductive principle, without which the male element would be superfluous, we have in the case of this chestnut the more recent, instead of the latest, organ abort with the failure of nutrition. It is not for me to reconcile these contradictions. My province is the humbler part, — merely to record the facts I see.

Here these facts are that the female flowers are in the strongest lines of nutrition; and that, with the failure of nutrition, the female organs are the first to disappear.

* Herbert Spencer, "Principles of Biology," p. 70.

4. OBSERVATIONS ON SEEDLING COMPASS PLANTS (SILPHIUM LACINIATUM). By THOMAS HILL, of Waltham, Mass.

GENERAL BENJAMIN ALVORD first described the Compass Plant to the learned men at Cambridge; and the poet Longfellow, who was among the most interested of the listeners, soon after introduced it, in his "Evangeline," to the civilized world. In 1848, General Alvord called the attention of this Association to the plant. In 1863 I measured the bearing of about one hundred leaves in a group of plants near Chicago; and the measurements, published in "Silliman's Journal," showed that the radical leaves of young plants gave the meridian with great accuracy.

In June, 1869, I was going, on a dark, rainy day, from Omaha to Chicago, and amused myself by estimating the bearing of the track, from the leaves of Silphium in the prairie, as we passed at full speed. Three times in the course of the day, the patches of plants were near mile-posts; and I made a memorandum of the estimated bearing at those posts as 35°, 75°, and 90°. In Chicago, I obtained, by the kindness of officers of the Chicago and North-western Railroad, opportunity to measure the bearings on detailed maps, and found them to be, at those points, 31°, 78°, and 90°.

In October, 1869, being detained by an accident at Tama, on the same road, I gathered seed. The plant is a very sparse bearer; and, after long labor in the frosted prairie, I obtained only twenty or twenty-five sound seeds. From these I raised in June, of the present year, about a dozen seedlings.

The radical leaves are entire, lanceolate, long petioled, and vertical; and begin when about eight or ten centimetres in height (my tallest are now about twice as high) to turn toward the meridian, twisting the petiole in its whole length as they do so.

I give a table of the direction of each leaf, and exhibit a diagram of the direction of those leaves which, being old enough to have been measured three times, escaped drouth and insects. Ten of the fourteen thus measured exhibit very decided polarity.

The dry weather has been unfavorable for the experiments by which I hope in a more favorable summer, hereafter, to show the causes of this phenomenon, and of its non-appearance in some plants and places. For its perfection it needs rapid growth, and an unbroken horizon.

Each horizontal line in the following table gives the record of position of a single leaf, so that the table furnishes a partial record of twenty-two leaves.

Original Position.	July 11.	July 16.	August 15.
72 E.	72 W.	65 W.	65 W.
70 E.	1 W.	2 W.	1 W.
71 E.	2 W.	17 W.	2 W.
4 W.	1 W.	1 E.	7 E.
80 E.	10 E.	2 E.	2 W.
80 E.	75 W.	70 W.	70 W.
27 E.	4 W.	2 W.	Dead.
27 E.	10 W.	1 E.	"
61 E.	61 E.	60 E.	55 E.
61 E.	2 W.	4 E.	2 E.
80 E.	80 E.	70 E.	70 E.
20 E.	16 W.	11 W.	7 W.
39 E.	25 W.	10 W.	5 W.
1 W.	21 W.	Dead.	Dead.
1 W.	18 W.	"	"
20 E.	16 W.	15 W.	"
39 E.	6 W.	Dead.	"
18 W.	Broken.	"	"
Uncertain.	Not up.	Not up.	1 E.
"	"	"	7 W.
"	"	"	2 E.
"	"	"	15 E.

5. INVESTIGATIONS ON THE DEVELOPMENT OF THE YEAST, OR ZYMOTIC FUNGUS. By THEODORE HILGARD, of St. Louis, Missouri.

1. *Morphological Development of the Yeast Fungus.*

THE subject-material of the following monograph is, for the greater part, as yet but very imperfectly understood in this connection, on account of its microscopic complexity, evanescent minuteness, and the consequent difficulty of its perfect identification in its various phases, which is obtainable only by a connected experimental investigation. The latter having been incidentally conducted by me through about fifteen years (so far as swamp, well, and river waters are concerned), and also latterly more systematically explored, it was deemed advisable to refer the detailed description of so much "punctilious" diagnostic detail to a plate; with a view to rendering the reader and the practical microscopist somewhat familiar with the important object whose intense action, both in a beneficent and injurious sense, cannot be overrated. Its morphic processes, however, remain almost entirely unknown to the public; although its functions have largely served to "typify" the mysterious agencies of malarious and contagious diseases. That type of action, however, has lately been made responsible for morbid processes exclusively, and in this sense been also exclusively referred to some hypothetical, invading, extraneous, and independent parasites. It typifies no less, however, all the healthy specific functions, whether digestive, assimilative, or secretive, as manifested in the entire living kingdom, and whereof it actually furnishes the best *exposé* itself. Partly also has the peculiar and "specific" agency proper of this fungus been misinterpreted for that of other hypothetical ones never yet distinctively and comparatively brought forward; and partly do the demonstrable ones, which like the "Muscardine" act as specific zymotic parasites, only serve to enhance by analogy the all-importance of the true Yeast, or Zymotic Fungus.

Explanation of Plate.—The successive figures represent a series of experimental developments in continuity, illustrating the specific unity of all the common forms of mould and yeast as well as of all putrid decomposition.

The adult forms, Mucor-heads, or seed-vessels, are represented

along the upper margin; the scums and original mycelia, with

DEVELOPMENTS OF ZYMOTIC FUNGUS.

Illustration from C. H. Frings' "Zymotechnic News," February, 1870.

Figures magnified 300—400 diameters, or about fifty million times in bulk. The smut-bearing seed-vessels in figs. 5, 6, 7, 11 and 12, only half that linear size.

pencilled florition (*penicillium glaucum*) along the lower; segmented forms (*oidium*,* *torula*, etc.), on either side.

* Name derived from οἰδάω, to *swell*. The Greek verb no doubt is itself compounded of 'Ὠὸν, an *egg*, and of εἴδω, to appear, see, or *resemble*.

It would be "carrying owls to Athens," if we would attempt to supersede

The centre represents (around 8) the vibrionic, truly fermentive element, enacting the lactic, alcoholic, and cadaverous fermentations and afterwards generating the "yeast-cells" (below 8), from which these elements are again disgorged when opportunity is given. Old, crusty, and macerated fragments redissolving into the naked vibratile molecules, or fermentic vibrios (above 8). The latter (to the left), by lengthwise inosculation, are seen to connect singly, or by pairs and strings, into the delicate, naked, vibrionic single-file threads ("serpents," or "leptothrix") forming short weltering curves ("churners") and long, revolving, "archimedean spirals," with "spinning butt-ends." Next, becoming coated, they are seen either directly elongated into the fibres of the water-pest (leptomitus, below), or else, as in all fermentible fruit juices and mashes, they are seen dropsically enlarged and varicose. Becoming figure 8-shaped or "waisted" at the joints, the latter ramify into irregular, secondary, tertiary, etc., jointlets in figure rather resembling the "fingered yeast" pencils: (below the leptomitus, and between 9 and 13), only more rounded, and altogether stemless, somewhat like ramified potatoes. Separating at the joints, the now so-called *hormiscium*, or necklace-yeast, dissolves into the free-beaded, globular yeast, or *cryptococcus*, such as beer yeast. The latter form then, through several generations, repeats itself by spicular prolapse. Fine spicular darts appear, erect on end, in various places at the circumference; and, rapidly swelling, represent smaller cocoon-shaped cells, which swell and round again, while the old cell-coat substantially dissolves by maceration, the contents having priorily passed into the spiculæ.* Fig. 11 represents the yeast-cell elongated into a mycelium, which readily segments into cylindric fragments (*oidium lactis*), while at the same time rearing its pencilled floritions and mucorine seed-vessels on one identical fibre with the "oidium." Some submerged pencils, and also some turgid segments (*pseudo*-" Zoögloea"), are seen emitting coated *bacteria* which reproduce the finest "leptomitus" fibre.

the classical compound, by forging a modern one like "Oïdium" (with the *trema*). The handbooks use the antique form.

* The spiculæ are at first only recognizable in their long diameter of about 1-400 line, before the cross diameter becomes distinctly appreciable. It thus resembles an incipient crack in the surface of glass. In consideration of apparently analogous transformations, arising out of the porrected vibratory flagellum of moss-spawns ("Euglena"), it might be suggested that the spiculæ are the exserted "vibratile cilia," or, rather, the flagellum of the intra-cellular vibrios.

(The latter, as "leptomitus lacteus," again dissects into globular individual molecular germs 1-2000 line diameter).

Fig. 1.—Derived from rotten cabbage. A single crescented roll (*fusidium*, or "Fusisporium," "Fusarium," "Næmaspora," "Menispora," etc., etc.), bearing, on one unbroken fibre, the crescentiferous seed-vessels ("Mucor fusiger"); crescentiferous pedicels; short spawning-clubs ("Hemicyphe"? "Azygites"), with a dissective frizzle of "flying spawns" ("sporidia," De Bary. Comp. also figs. 7, and 12, below the number); and the antennate mildew (*oidium monilioides*), different from the blight on *Poa pratensis* (the "blue grass" of farmers). A piece of its blighted blade, kept wet under the microscope, exhibited the rusty speck (from which *its* "oidium monilioides" emanated) pushing strong fibres upon the glass slips; the former bearing, in one uninterrupted continuity, on one unbroken fibre, its own antennate mildew, together with a fingered yeast (fig. 13, to the left) and pupiform spores (fig. 7; also fig. 15, upper corner). The latter, when massively produced in fall, are called "Gen. Phragmidium"; on cabbages, mouldy herbaria, tea, or fungi, "Gen. Cladosporium," "Septosporium," etc.; on wheat-rust, *teleutospores*, De Bary.

Fig. 2.—A bead of the antennate mildew, taken from the preceding specimen, and germinated upon apple-peel. Besides repeating the antennate mildew, its stem also produces, on the same unbroken fibre, the characteristic *penicillium glaucum*, etc., or blue mould of fruits and wines; differing only in form, not in species, from the blue mould of bread, peach preserves, and peach gum, viz., the *aspergillus glaucus*, etc., represented in fig. 10.

Fig. 3.—Limpid fermentic juice, profluent from spontaneously dissolving fibre of same. Develops naked "vibrios," coated "bacteria," and a compact hyaline gelatine of yeast-molecules. Some rather bulky tissues thus deliquesce into a mere faint trail.

Fig. 4.—Same as in fig. 1; from cracks of crockery enamel. The "germinal log-chains" (of bi-nuclear cells) are bred out of fresh penicillian beads. Its older pencil beads turn of a tourmaline color. The whole production is at last uniformly diffluent into a crimson jam, or "blood-in-bread." The old wheel-and-axle-shaped beads, when sown on human saliva, within twelve hours produced —

Fig. 5.—A very stout mycelium; roughish-looking and "medullary dotted," with actively circulating (intra-cellular enclosed) vibrios. Rapidly multiplies by globular cross-segmentation, con-

tinuing same calibre. Dissecting rolls ("Oidium"), stalks, and crescents ("Fusidium") produced on same unbroken and unseptated fibre, together with its seed-vessel, or "Mucor." The latter partly transuding its spores, in this case, which adhere to the surface ("Gen. Periconia"). Near fig. 9: same development, but with smooth fibre; obtained from indistinct dot on matutinal saliva. The mycelium is very much foreshortened in the representation.

Fig. 6.—Crescental roll of same (also of fig. 1), developing into clusters of stemless seed-vessels (comp., in fig. 11, the erect files). Also found in the gray, slimy coats of wet cellar-walls; the viscid spawns erumpent in brown pimples, while the mycelium represents a "leptomitus" coat, its fibres topped off with slender crescents ("Næmaspora," "Blennoria," etc.).

Fig. 7.—Dark, leathery mucor-heads (seed-vessels), as formed when exposed to the open air ("Ascophora," "Mucor," etc.): *e. g.*, on sweet potatoes; in black-moulded lemons; on crout, balsams, cream, and also under water. Those exserted above water are flaky evanescent and sooty crumbling; those in very humid localities diffluent ("Hydrophora"). (Compare also figs. 5, 9, 12, and 14).

Varied germination of globular, sooty seed (smut, or uredospores), discharged from air-dry, matured seed-vessels of Zymotic Fungus. Development, either directly or by moulting, into "pupiform germs" (*teleutospores*, "septosporium," etc.). The latter put forth black, root-like mycelia, which in the water branch into strands of water-pest. Others (in damp spots, etc.) develop a "spawning frizzle," detaching dustlike "sporidia," De Bary. Others, effete and macerating, like all old débris of the Zymotic Fungus, bodily dissolve into their own vibrionic spawns, in which condition they remain unchanged for years together, as, *e. g.*, was the case with the mycoderm and leptomitus of old wine-casks, filled with Mississippi water, and that of the latter itself. The original liquid and luxuriant mycoderm remained unaltered for a period of three years, when the corked glass tube, which the water filled three-fourths of its height, was accidentally broken. Mycoderm after mycoderm, blooming with the *penicillium glaucum*, was produced at the surface, and then, breaking down, settled at the bottom to the height of one-half of an inch, layer upon layer, no further change occurring after the last one had sunk, and the water being left clear above, and void of taste or smell.

Fig. 8.—Simple, naked, fermentic sarcode vibrios; of a globular

shape, about $\frac{1}{8000}$ line or less in diameter; with a vibratory organ, not distinctly discernible, but causing a saltatory motion, or jerks, often tenfold their own diameter. Frequent experiments have satisfied me that without the presence of any other (cell or sarcode) development, they are by themselves sufficient to enact the entire alcoholic, lactic, and putrid (cadaverous) fermentation, or decomposition, without aid from other organs.

Judging from Liebig's analysis of the active ingredient of the "yeast" cells, the stoichiometric constitution of the vibrionic sarcode is to a nicety identical with that of the "muscular fibre" proper. In the progress of decomposition, the fibrine of the muscle seems to "dissolve," as it were, substantially, into these naked sarcode molecules,* which, however, on meat find no material for forming into cells, or so-called "yeast," for want of cellulose. They are, however, the true active principle, and *de facto* actually constitute the ferment of the yeast.

The vibrios speedily then arrange into single file threads, by longitudinal coaptation, or "inosculation" (different from the so-called "copulation of cells," there being no cell-membrane). When thus falling into ranks, the terminal vibrio at either end retains its size and action; while the intermediate ones loose their previous diameter, by the disappearance of what had produced a sort of "halo," surrounding the sarcode molecule proper. It is thus that in the process of formation of this single file production, by some authors called "leptothrix,"* the existence of a cell-membrane has been emphasized by Professor Hallier. This, however, is a mistake. The "halo" remains so long as there are only a pair; but so soon as the pair has united with another pair, or sets of pairs, or so soon as a longer chain is formed, all the intermediate vibrios loose that halo, or false "cell-membrane," which forms a dim vibrating zone around the molecule.

This process of fidgeting and spinning at the ends, where two short sprigs or "churners" are engaged, as if in a violent combat, twirling "head to head," has been frequently mistaken for a

* This is evidently the first species of the first genus of Ehrenberg's "Infusoria," — "*Monas Crepusculum;* hyaline; appearing to the naked eyes as a whitish mass; spherical, agile, carnivorous; never exceeding 1-500 millimetre in length. Abode, Berlin." See "Traité Pratique du Microscope, etc., par L. Mandl, et Recherches sur l'Organization des Animaux Infusoires, par C. G. Ehrenberg. Paris and London, 1839." All the infinitesimal spawns of dissolving (animal) "infusorial" yolks of Ciliata are, however, of the same size, and form dense curds, or clouds, on the surface of aquaria, etc.

cross-division * into smaller parts. Contrary to the supposed method, and to that of the well-known self-division of cells, these sarcode bodies unite and arrange in single file, as properly stated by Professor Hallier and others. † The longer coils are often found in stinking water, among macerating converfæ, and have an (often very violent) rotary motion.‡ They sometimes acquire as many as twelve rounds of coil, and (particularly in the night) are seen adhering to the glass slip, becoming "still," and exuding a membrane. These longer, spirally undulate files, or coils, now lengthen directly into unbranched single shreds of the "leptomitus" (above), of which they form the inward "life-thread," so to speak.

The shorter, merely curved ones — "churning," butting, spinning § and as it were delving into the corruptible or fermentible matter,

* This is what Ehrenberg (above) called his "twenty-seventh genus: *Vibrio*. Form, that of a chain, filiform by imperfect spontaneous division; flexible as serpents;" *i. e.*, archimedean-revolving. "First species: *Vibrio Lineola*. Minute cylindric frustules, a little flexible (curved ?), round at both ends; joints not very distinct, almost spherical; water-colored, 1-300—1-1000 of a line." It would have been interesting to learn about their abode, or menstruum (necessarily a liquid). The locality given is "Berlin, Copenhagen, Paris, Ingolstadt, Petropawlosk, Tobolsk, Tobol," etc.

† In this state it forms Ehrenberg's "ninth genus: *Monade serpent*, *Ophidomonas*." It consists of one single species, "Monade serpent de Iéna, *Oph. Jenensis*. The body spirally twisted, very delicate, obtuse at both ends" (occasionally: see Zymotic Agencies below) "of a brownish-olive color, 1-24 millimetre (long). *Hab:* Ziegenhain, near Jena" (famed for its spirally twisted *baculi* for the student). This term seems to "claim priority" against that of "leptothrix," and is more descriptive.

‡ This process of cell-generation by *synthesis* of molecules, has its analogy in a widely operative (but almost entirely unknown) process of massive co-cementation; as in the case of penicillium tufts enlarging into periconia forms (fig. 18) and Mucor Mucedo; as do the aspergillus forms (fig. 10). Some massive sphæria crusts originate by co-cementation of piled "botrytis" spores (or "trichothecium") etc.

§ This fact is erroneously denied by Professor Hallier, who doubtless had *torpid* "vipers" to do with. The vibrios become very violently active only at or above a temperature of about 16° C. Below that, they are very apt to remain single; and, slowly acquiring a confine, or membrane, form into individual globules of the true globular (or "cryptococcus") yeast; as, *e. g.*, with milk turned into clabber, etc.

This motion is more readily observable in the case of colored vibrios, such as the orange ones; *e. g.*, of the well-known blackberry rust. Its vibrios have nearly the threefold diameter or twenty to thirty fold the bulk, of the fermentic ones. They are seen persistently pushing and butting into the chlorophyll of leaves when presented, in a floundering, semi archimedean-motion. Their "ophidomonas," or leptothrix-serpent, forms not into spirals, but into "fence" like zig-zags.

and also vividly swarming about — after a while become likewise coated, by exuding a very delicate membrane. They now assume a sort of dropsical appearance; and swelling into a varicose-ramifying and dissecting fabric (resembling the ramified and phalangoid foreshortened "fingered yeast," fig. 13, left end, but for being stemless), they now form the so-called "hormiscium," or necklace yeast. The same, however, is likewise produced (fig. 13) by direct development from crumbling pencil strings; sprouting, *in continuo* and *in loco*, into the same form of necklace yeast.

The detached hormiscium joints partly repeat sprouting in the form of the necklace yeast; partly remaining single, they round into globules, and thus form the true globular beer yeast, or cryptococcus.

The latter through several generations now multiplies by the extrusion of extremely delicate splinters (spiculæ), which again, standing on end, rapidly swell into oblong cells. The latter soon round off, and detach themselves; while the mother-cell appears exhausted, collapsed, and macerating.

The "mycoderm," or mother of vinegar, consists exclusively of naked vibrionic files, felted into a dense and homogeneously resistant tangle. The "churners" (short "ophiomonads," or "leptothrix" serpents), however, are here actually imbedded into a hyaline, apparently perfectly "amorphous" gelatine, which appears to form the greater part of the bulk. On its surface "small vesicles" are afterwards observed, which, however, prove to be separately developed and isolated terminal cells, sprung from the vibrionic sarcode filaments. They are acutish shuttle-shaped and segmentative, and constitute the snow-white scums, or "våppa;" and they are supposed to be the agents of acetification.

Fig. 9. — Pupiform seed, expelling germinal pellets resembling those of fig. 5; while at the same time taking root (as "Rhizopus nigricans," etc.), — black-booted, as it were, — and also sending out runners ("Mucor stolonifer"), seed-stalks ("Ascophora Mucedo, Mucor caninus," etc., etc.), and aspergillus stalks ("Aspergillus glaucus"): the (blue) mould of bread and peach-preserves (not that of apples, etc.) In this tri-compound form, uniting the "Mucor," the "Piptocephalis," and the "Aspergillus," — thence sprouted on one individual root — it is figured as taken from rotten tea-leaves.

At the bulbous top of its stem, resembling a drum-stick, it sends forth either the long, diverging bead strings of large ellipsoidal

beads of a blue color, which often turns black ("Aspergillus glaucus"); or else it swells into a large mucor-head, which retains a similar knob (columella) enclosed at its base ("Mucor").

When very succulent, as on preserves, the incipient seed-vessel in a juvenile condition is often seen "transuding" immature spores, as it were; which, being rapidly succeeded by new layers (probably on their periphery), often becomes so densely crowded as to form a compact mosaic of prismatic cells, concentrically stratified around the large knob ("Piptocephalis Freseniana," or "Periconia sp.") It is a highly important observation in the study of life phenomena, that this versatile, fundamental form of assimilative and digestive catalytic life, as embodied in the Zymotic Fungus, is very apt to repeat the form attained, so long as the substance remains the same. On a decayed body, which has already produced the seed vessel, its own seed will reproduce seed-vessel mycelia, on the same ground. Add some fruit-juice, or sow it upon intact fruit, it will first produce the pencil-bearing mycelia; and its pencil beads will reproduce the pencil-bearing form, until the nitrogenous fermentation is attained, when they form seed-vessel mycelia. It is thus that the aspergillus, or radiate drum-stick form, will also repeat for a while; although it strongly inclines to form yellow, stalked, or stemless seed-vessels (the original "Mucor Mucedo" L.) by confluence. The "pupified," or hibernating, dark-skinned tessellated cell-packs ("schizosporangia," Hallier), such as are found hibernating in the gum-knolls of peach-trees, etc., converting the same into a sort of "burnt India-rubber" like mass, sprout into extensive annular-beaded mycelia of a dusky color, and on the inspissation of the gum, meandering like the snakes of the head of Gorgo; and these meandering, serpentine mycelia, when occasion offers, directly issue into a crop of the *aspergillus glaucus* form. In rotten apples, however, where the septic mycelium is of a similar description, it is only penicilliferous, etc.

Fig. 10. — The entire "aspergillus" head, — resembling that of ecclesiastic service, — seen confluent into a stalked, yellow seed-vessel, with the remaining blue beads of strings still projecting (also called a "Periconia"). Or else, its delapidated, detached strings and single beads, becoming more or less confluent by spontaneous maceration and combination (a process widely observable in the formation of larger fungi, likewise), swell and augment into the king's-yellow, kid-like layers of sporangia ("Mucor Mucedo L."), which form the cover of mouldy peach-preserves. They are like-

wise found originating, in a corresponding manner, directly from the "mealy-heads" (fig. 13) on apple-preserves, out of *penicillium glaucum v. crustaceum.* (They have been misnamed "Eurotium.")

These layers of yellow, stemless sporangia, scantily interlaced with roughish meandering fibres (elongated beads), constitute, no doubt, the most massive and indubitably "adult form" of the Yeast Fungus. This form directly refers it to the closest relationship with the "frothy-smut" cakes of Æthalium and Spumaria, and the smut diseases generally. It is also frequently found on the honeyed drops of hickory, cut in sap; on hackberry, likewise; on extract of valerian and extract of beef, always preceded by the blue (or gray and blackish) aspergillus; while extract of opii moulds with the blue pencil and black-headed mucor-mycelia.

The seeds of the yellow sporangia are of a watery-yellow color themselves, and are found apparently conglobated, in a recent condition, in *packs of eight.*

This is a regular number of spores occurring in the "asci," or entrail-like follicles, which constitute the seminiferous stratum of the cupular and nucleolar fungi (Pezizeæ and Sphæriaceæ) no less than of all the Lichens.

In the case of the Yeast Fungus, however, these "asci" are globular, and not stratified, but borne on delicate, ramifying, fibrous connections, forming into a mass. In the case of Chætomium,—a furry nucleolar fungillus, otherwise resembling the yeast-mucor,—the slender octosporous asci are doubled up, and thus form a sort of transition between the Sphæriaceæ and Mucedineæ, or "smutted" fungi. The seed of the yellow yeast-mucor, when brought upon intact gumless fruits, there at once forms mycelia, producing the blue pencil of vinous fermented substances (such as grapes, rotten apples, and lemons.) All these organs are apt to sprout at once into fibres, when checked in their onward development.

Fig. 11.—The lactic fermentation of sweet milk into clabber, as well as that of cornmeal mashes, at a low temperature, is often completely enacted without the presence of any other form of the yeast-fungus but its naked vibrios and vibrionic "churners." The incessant action of the latter, which under a four hundred magnifying power are barely discernible to a practised eye, cause the milk-globules to butt against one another; thereby bringing about a so-called "molecular" motion of the latter. At last the vibrios, or short churners, appear individually coated, as a direct production of the free cryptococcus-yeast, not effected by dissec-

tion of the hormiscium, and also distinct from the acetic, shuttle-shaped scum-cells, erroneously called a "mycoderm" by recent writers on the subject. The dry yeast, when added to a fresh mash, is seen to swell, and to discharge myriads of single, naked vibrionic particles, as correctly stated by Professor E. Hallier; while the original membrane macerates into a clear gelatinous substance, entirely dissolving into vibrionic matter; partly directly, partly through assimilation by the omnipresent surrounding living germs.

Each yeast-globule, like any other molecule of the fungus, can directly elongate, or sprout, into a mycelium, whose fibres will readily dissect, particularly on substances already gone through the lactic fermentation (above) into cylindric joints, — called "Oidium lactis," of glossy lustre and of snowy whiteness; as often observable, in summer, on corrupt tomatoes, or mouldy potato dishes; on clabber, curds, cream, and the meagre clabber-cheese (Handkaese) of Germany. It first appears on the compact curds as a dull yellowish rind of erect "oidium" velvet, and in this stage the cheese is unhealthy (savoring of mouldy potatoes, etc.). The cheese then undergoes a strongly marked alcoholic fermentation, and is still unhealthy. It is only after the peculiar "cheese-odor' becomes marked, that its unhealthy action ceases, and it becomes an excellent stomachic and digestive.

The internal, white substance of the cheese then shows not a trace of the "oidium-lactis" form; while its brownish, gelatinous, semi-liquid rind is substantially composed of the oidium-lactis vegetation. It directly sprouts into *penicillium glaucum*, of the usual forms; and its decalvating beadlets again directly enlarge into oidium-stubbles. They are also known to produce, directly, the beads of beer-yeast; and in fig. 5 a *putrid* development of the pencil-beads is depicted.

At last the oidium-cells become diffluent, and not a trace of cell-coats remains visible. Of this character the perfected, and no longer unhealthy, Limburg cheese partakes; and it would be very difficult indeed to detect any "cellulose" there, in any shape whatever.

Aside from the produce of the dairy, sweet or sour wine and the daily bread we eat, all preserved greens — such as krout, beans, cucumbers, tomatoes, and in fact all pickles — had to undergo a preparatory degree of fermentation, fitting it for the human assimilative economy. In this respect, it is particularly the presence of common salt which insures a healthy quality to the fermentic

changes to be wrought; limiting the putrid, and accordingly favoring the purely lactic, alcoholic, and acetic, adaptive changes of constitution. Under these circumstances greens will ferment in the lactic sense; but the "oidium lactis" is by no means present, unless when "decay," through the formation of mycelia — dissecting into oidium-joints, — is initiated.

The latter takes place, also, in the normal decay of all human stools; the healthy no less than all diarrhœic, dysenteric, typhoid, choleratic or bilious fæces alike. It also forms on all human slime, essentially derived from the lactic and lymphatic system, which permeates the entire regenerative fabric. Hence it characterizes all effete offal, and abundantly appears, — together with the wine-ferment, or *penicillium glaucum*, — on the putrid decomposition of the human body, in all observed cases.

When arising from the cylindric segmentation, the penicillium, or florition-stage of the fungus, sometimes forms by actual segmentation and parallel coaptation of formerly detached segments, in testimony of its origin, as also visible, in a corresponding manner, on the crescental ramifications in fig. 4, in the log-chain mycelia sprung from pencil-beads. Collaterally, however, in both cases, the normal, *cereus*-like embranched pencils arise.

In very many cases, the submerged oidium, or cylindric-joints, — *e. g.*, when found on decaying confervæ, in old tea or coffee, — are frequently seen to enlarge and disgorge their oscillating punctiform contents as a mass of bacteria, cohering in slowly advancing, tear-like polypoid masses; otherwise closely resembling the (animal) "infusorial" germinal clouds, but for the great vivacity of the fermentic bacteria; while the infusorial dots are but gradually growing forwards, as it were, and, when once movable, start off.

A similar polypoid discharge of bacterial slime takes place from the macerated bead-pencils, when gradually drawn under water, as observable, *e. g.*, on the mouldy floating islands formed on the same decomposing decoctions. The confluent beads, macerating, exude a scab (like a floating grain of quartz, as it were), delicate as a butterfly's scales, and under whose cover the bacteria disengage, and form into comet-like leptomitus-strands. It is this polypoid bacterial discharge which Klob (in his "Researches on the Corruption of Choleratic Bowel Contents") has mistaken for "*Zoögloea Termo*," Cohn. The latter, however, are infusorial yolks.

The fungine bacteria are single vibrios, each endowed with a shuttle-shaped cell-coat, and not growing by mutual inosculation.

The spontaneous discharges of deliquescent fibres leave mostly the bacterial form behind, as an evanescent trail, spontaneously dissipated in every direction. The sporangial fibres, particularly, frequently attract juices to a certain spot; forming a drop, or "cystern," wherein the bacteria acquire a larger size. This has been mistaken for a "collateral fructification, producing sporangia," by some writers. Fibres, for want of moisture, will often adhere alongside, and there be found deliquescent.

Fig. 12.—On substances suited to the production of seed-vessels; *e. g.*, on curds or beer-yeast (whence the figure is taken), some oidium-joints, acquiring considerable size and punctiform contents, will sprout a ramified mycelium, bearing mucor-heads (pallid, grayish, black, or brownish). As with all larger mucor-vessels, the stems are at first knobbed like a probe; and here quite a close analogy to the incipient formation of the aspergillus obtains (above). The vesicle itself finally contains a similar knob, or columella, and was thus defined as "Mucor clavatus," Link.

Fig. 12 also exhibits the occasional co-occurrence of the blue pencil on mucor-stems, *in continuo*. Projected in upon the often hood-like compressed, empty vesicle, the figure exhibits certain serial beads, exserted above water; which, on crumbling down, acquire in the water a thickish rind, and enlarge to a stemless, watant mucor-vessel, analogous to fig. 6.

Fig. 13.—Penicilliferous mycelia of the Yeast Fungus. Derived from the shuttle-shaped scum-particles (vappa), which, arising from a mycoderm, are supposed to effect the "acetic" fermentation. The rather pointed floating fibres, ramifying and frequently septated, or even dissected, now become studded with the blue pencil (right-hand corner; compare also figs. 12, 11, 3 and 4), as found on all sour fruit (when not too gummose), and forking by almost parallel, fascicular-branching "metacarpals," so to speak (as in the skeleton of a hand). These are produced sideways, in the manner of the branches of an erect Cereus (sub-parallel); while on lactic-fermented substances, the joints apparently separate, and adhere lengthwise, and even some of the "crescentiferous trestles" (figs. 1 and 4) occasionally turn to pencil-tufts.

Farthest to the left, we figure the "fingered-yeast" pencil ("*Pc. chlorinum, cladosporioides,*" etc.). It is partly directly developed on a stem, or the fallen bead-strings of a pencil (on a bung or a grape-berry) directly developed into it, *in situ;* their beads elongating and ramifying (like the necklace-yeast) into joints of

decreasing size ("foreshortened," or in the manner of "phalanges").*

The joints readily swell into the black pupified spores ("Cladosporium, Septosporium," etc., etc. Compare also figs. 7 and 15. Similar forms occur in a great many other fungine developments,—of Stemonitis, Erysibe, Puccinia populi, etc.). They also produce singly, as on a pipette—or on whorled, pipette-jointed garlands—a chocolate-colored botrytis, which forms the enormous quantities of Indian-red dust; *e. g.*, on old rotten sweet potatoes. Its globular heads crumble into oblong spores, from which springs a slender lithe, few-seeded, diffluent mucor, which appears like a dew-drop ("Mucór racemosus," "Hydrophoranetella").

In the background we represent a "pencil-head,"—blue, white,

* Similar homologous forms frequently occur; *e. g.*, in the development of *Stemonitis physaroides* (a line-high, small, pin-head-shaped, chocolate-colored eruption on wet pine-boards); the previously gelatinous head at first becoming "silvered over" with a blue (or amber-yellow) penicillium, quickly converted into the fingered-yeast (above) shape; and then each joint develops often into short "pupiform" spores (like in figs. 7, 15), etc. When bred between glass slips, its "penicillium" form is produced by an apical whorl of about one-half dozen of short clavate "carpals," forming a sort of cupule; from which ascends a fascicle of as many cohering files of pencil-beads,—with a great many variations, however.

Again, in the florition-stage of Chætomium (the sea-urchin-like mould-sporangia on old fibres), the single pencil-files are borne, by threes, on simple or ternately compound, pipetted pedicels, crowded garland-like around long cobwebby threads (as are the crystals of rock-candy along a thread). The beads here enlarge (as in the zymotic aspergillus, fig. 10), and form pearly-hued, shiny, "acinoid" pellets (a silvery "botrytis" form. These, after repeated changes, are developed into "Chætomium." Great care is therefore requisite, in order to discriminate, or to identify, the "penicillia" by breeding round.

Another pencil-like development forms a grave disease of verbenas, etc., in flower-pots, or in boxes in contact with pine-wood percolation (saw-dust of pine, etc.), and probably constitutes the severe and destructive disease of the Crocus-plantations in Southern Europe.

A blue mould, like a (blue) white frost-bloom, is seen erumpent out of the naked ground, and is composed of scraggy-repent, ramulose garlands of a stunted-like aspergillus; of a blue color, only very few (1–6) beaded, and rapidly cementing into a botrytis-form. The latter (like our mealy-heads in fig. 13) push long filaments of a yellow color, light and large as cobwebs, in secure places becoming condensed into a sort of smooth slag, or gravel-like grains (like spatterings from fritters) called "Rhizoctonium" (root-killer). The yellow fibre or cobwebs, afterwards freely break forth from the same ground and, shape into a loose web, confluent into an omelette-like, resupinately effuse *Phlebiavaga* (or similar denomination) of the tetrasporous, agaricine fungi; which is again, *in loco*, substantially converted into the gravelly rhizoctonium.

brown, yellow, black, etc., — as frequently found on old cheese and dry moulded meat, moulded twigs, etc. It is composed of a multitude of simple pencil-tufts aggregated around the forking point, so as to form a globular umbel, much finer-beaded, however, than is the aspergillus form, fig. 10. Co-cementing its beadlets, it also forms a dusty "mealy-head," and is also called a "Periconia." Where many pencil-tufts arise in a column (as observable, *e. g.*, on old goose grease, etc.), they all co-cement into fatty-looking, little puff-balls, of small pin-head size. From the dust of the mealy-heads spring long fibrils, terminating into partly ramified strings of globular, very highly refractive beads, or so-called (fig. 14) "coralline bead-strings" (Torula). They are at first clear; and in this condition become partly highly inflated, sprouting stalked seed-vessels (compare fig. 12); partly do they segregate into oblique lemon-shaped beads, which produce another distant-beaded "aspergillus" or "penicillium" form (right-hand corner). It often assumes the tint of red coral; and its (disciform) terminal beads are seen to sprout a spawning frizzle, such as also represented in figs. 1 and 7.

Fig. 15. — Represents forms of decay, as found on decaying tea-leaves, cabbage, and the charcoal filters of a sugar refinery. Pupiform cells (Cladosporium, Septosporium), are variously produced on all final decay of substances. Their blackish mycelia are sometimes developed from antennate mildew (fig. 1, etc.), as sometimes from the rusty specks (puccinia) of blue-grass, covered with the snowy blight which bears the "pupiform bottles," the "fingered yeast," and "oidium monilioides," all on one undivided fibre. They also arise from very delicate fibres, acquiring inflated joints in single file. Some produce (on tea-leaves and charcoal-filters) a very stout, dissecting fibre (or oidium), with coral-like dissecting and lemon-beaded arbuscular summits. These assume a pink (miniate) color, and dilapidate into a most subtle molecular powder of the same color, each molecule redeveloping (on leaves in fig. 1) into a "fusidium," or crescent, and fibres whose tops detach one or two oblong joints, hanging in a drop; and which also directly assume the fusidium form.

These "coralline arbuscles" also directly sprout into pupiform spores and aspergilli. (See figure.) It is nearly the same in shape as the erect, antlered files (of oblique lemon-shaped spores) which form the well-known gray rot of peaches (*Oidium fructigenum*, *Torula fructigena*) abundant on all stone-fruit. This form is often as destructive to pears and the pear-tree as it is injurious to the

peach-tree, whose branches it infects. It also occurs in Europe, in the live flower of the Prunus Padus, and of the plum-tree, whose fruit it parasitically infects, converting it into empty, pimpled bladders, called in Germany "Narren" (fops). As a parasite, nestling in the live parts of the tree, it becomes of the highest practical importance to be acquainted with its developments. Its continual abode and hibernating place is the exuded gum of the wounded peach-tree. On the fruit, the parasite develops the gray coral mould ("*Torula fructigena*"), reproducing its own form so long as acids, etc., are present, either by sprouting anew directly from the fallen bead, or else, extruding, from a stout mycelium, at every cell-dissepiment, a girdle of very long, but extremely fine spiculæ, which rapidly grow into bulky fibres, repeating the "torula." When the contagion extends to the green stalk and branch, the beads extrude through their nozzled ends a globule, which readily sprouts into a very delicate, snowy, ramified floss, bearing clear botrydium-heads. The latter here consist of free "didymous" or "trichothecium" cells; oval and bipartite by a cross-partition. These copular cells, when fallen off and crumbled, give to the shrivelled peach or plum a well-known pinkish color. When alighting on the soaked gum, however, within a single night each copular (or "bipartite") cell increases to a huge size. The developed vibrionic contents make each compartment appear as a perfect globe, each crowned with one-half of the gelatinous, macerated cell-membrane, as with a skull-cap. The contents and gelatine soon become confluent into a lagoon of oscillating, colorless single vibrios, resembling the orange vibrios poured forth from the spores of wheat-rust or of the red-cedar galls. They now travel in galaxies of myriads upon myriads of individual contagious germs, wherever the flowing and spattering water carries them, — all over the surface of the tree, down to the wounded roots, and impregnating the soil; while those copular spores, which remain embedded upon the gum-knolls, by indurating and reviving as serpentine mycelia, perpetuate the infection.

I have seen the same "Oidium, or Torula fructigena," on pears (which abound in gummose substances), and the crusty packs of tessellate cells, as of the peach-gum, developed in the liber of the infected pear-tree, as found on specimens submitted to me for examination. There can be no doubt that on both the peach and pear-tree the disease is identical, and mutually contagious.

As to the specific nature of this parasite, the development of the

serpentine fibrés directly into *Aspergillus glaucus* (as found on bread and on peach-preserves) argues the destructive peach-rot to belong, likewise, to the series of the Zymotic Fungus.

Besides the enumerated forms, many others are at present fully known as belonging to this vast cycle of ferment developments. The cymose crowded "*tetrasporous sporangioles*"—well figured by De Bary and Worônin* (*pseudo*-genus "Melidium")—are frequently observed, and also spring as a globular umbel from semi-mature vesicles, when kept in damp air. A charming "botrytis" form (connected with the "hydrophora" form of seed-vessels) is the *Botrytis Fonesii* (*Chætocladium Fres.*†) of repeatedly whorled crowns or clouds of (fugacious or) "flying spores," each successive system of nebular coronets being itself centrally traversed by the naked axis, as with a crystal spear, etc. It furthermore appears that all forms quoted under the head of Gen. "Mucor," "Ascophora," "Hydrophora," and "Melidium" (aside from all "Aspergillus" and "Penicillium" forms, etc.)—belong to the same speciés, or the Zymotic Fungus; a "Mucor" by right.

2. *Congeners and Classification of the Yeast Fungus.*

The decay of the grape on the vine here requires a particular notice. All healthy, mature grapes ferment with the fermentic fungus, and mould with a florition form of its penicillium, which also rapidly develops into fingered yeast (as on wine-bungs), until putrid decomposition warrants the development of the (mucor) seed-vessels. The "mother of (wine-) vinegar," even when dried up and remoistened, produces ascending pencil-tufts, which on the older fibres are seen rapidly rounding into "pencil-heads;" the latter again condensing into grayish, ashy-looking "mealy-heads" (above). The immature, healthy grape-berry, in its turn, sprouts into a powerful aspergillus production; as of bread-mould, etc.

These are emphatically forms of the common mould, or Yeast Fungus.

As for the diseases parasitically incident to the living grape, their development phases remain up to this hour practically unstudied, unexplored, and apocryphal. It must here be stated

* "Beitraege zur Morphologie und Physiologie der Pilze, 2 te Reihe, Frankfurt a. M. Christian Winter," 1866, pp. v. and vi., figs. 1 and 2, as forms of Mucor Mucedo.

† Ibid., p. vi., fig. 11.

that, of the two forms of grape-mould occurring in the West, one is the "botrytis acinorum" (too well known to fungists to admit of any further modern synonyms being inflicted), which is widely spread through both hemispheres. Its white, oval sporules, adhering by fours to cruciate top-ends, form together a sort of slender grape-stalk with clustering spore-crowds. It differs in shape from both the chocolate-colored (pipette-whorled) botrytis of Zymotic Fungus (in fig. 13 of our plate), as well as from the "spear-crown" botrytis ("Fonesii") of same. This, however, by no means necessarily excludes it from the possibility of belonging to the Zymotic Fungus developments.

The well-known "botrytis acinorum" attacks the stalks and leaves of the grape-vine, causing the berry to wilt. The other form, of putrid character, is the *Phoma uvicola*,* or "grape-comedo," its salve-like, seminal contents (compare description of fig. 6) being protruded, like the nasal "comedo," by the contraction of the superficially innate, globular cyst; otherwise simpler than a (stemless) Mucor Mucedo, such as are found (extraneously), *e. g.*, upon peach-preserves. At all events, the phoma is a late form; adult, or sub-adult at least, — later than the "botrytis" phases of fungi generally,† — and hence might lay claims to being a derivative of the grape-botrytis; which, however, does not seem to occur on the same plant in the same year with the punctured rot, or comedo, as far as I have been enabled to ascertain as yet.

The phoma-spots, when slips containing them were watched developing between glass slides, under the microscope put forth luxuriant mycelia, whose fibres occasionally condensed into nucleolar convolutes; while others formed the most luxuriant garlands of some "botrytis" form, not clearly recognizable, however, on account of the intervening mass of fibres.

In the "*Systema Mycologicum*" of Elias Fries, this "*Phoma uvicola*" is missing; but similar or identical ones are described as

* "Phoma" (plur. phomata), — a "burn," or "scald," — derived from the Greek, is of neuter gender. "Uvicola," — *i. e.*, dweller on grapes, — a Latin masculine substantive, is added as surname. The apparently feminine form of the whole name has given rise to a misunderstanding of its gender.

† The adult "black-enamel" crust of *Sphæria effusa* on black-oak, etc., is derived from "*Trichothecium roseum*," the botrytis-form of the "red-gum pimple" of the branches of the same tree. Another (Indian-red crust) Sphæria, on hickory-hoops, etc., originates directly out of the massive co-cementation of the fallen copular spores of a (snow-white) "botrytis" of its own, which itself springs from an antennate or oidium form of its own.

occurring on the fallen leaves of willows ("*Phoma salignum*") in winter and spring — (thus filling up the season succeeding that of the grape-phoma); similarly on the aspen or cotton-wood ("*Phoma populi*"); and his "*Phoma pustula;*" on "fallen oak-leaves; in America likewise;" and "*Phoma tylarostomum*" on the nether surface (as usual) of leaves of the myrtle and Lardizabaleæ in Chili." A quite important item we moreover find with his "*Phoma filum*," viz., "found on the living leaves of the bindweed and aspen, and as a parasite (*sic*) upon the rust-spots of either, and also ('parasitically') on the *Phoma populi;*" *i. e.*, to all reasonable intents and purposes, the ultimate product of the rust of those leaves (in whose rust-cicatrices I have also found them, within the rust-tissues themselves), and also identical with *Phoma populi*, — the difference being only nominal, occurring both on the live and effete foliage, and thus evidently uniting all the rust and phoma seasons, and breeding innumerable sources of infection the whole year round in one unbroken circle. Attention has been called before now to the fact that the "barberry-blight" ("*Æcidium Berberidis*") breeds rust in wheat. The discovery of the facts thus construed was made or known in New England, and consequently "legislated upon" for about a century and a half. It was, nearly up to this day, hotly contested by the incumbents of chairs or "degrees" of botanical science, on the assumed ground of "established" diagnostic conceits. It is owing to the experimental labors of Oerstedt and of De Bary, that the microscopic, developmental proof of this fact, accredited in both hemispheres by the daily repeated circumstantial evidence among the practical farmers, has ultimately been established on an unimpeachable basis; gravely committing those "qualified," governmental repudiations on the other side of the Atlantic.

The white "antennate mildew" (or "*oidium monilioides*," fig. 1), so abundant on blue-grass (*Poa pratensis*) arises itself from a rusty mycelium, within the grass-blade; whence also, in fall, its pupiform phase ("Phragmidium") is produced, as in the case of microscopic development, mentioned *sub* "fig. 1." In its "fingered-yeast" productions (ibid., also *sub* fig. 13) it resembles also those of the cotton-wood rust. From this it may be inferred that the rust-diseases, when once fully traced, will furnish a parallel to the Zymotic Fungus.

Notwithstanding the excellent experiments of Professor A. de Bary, of Jena, the full development of wheat-rust is not yet ascer-

tained. I have found a "rust" (apparently coinciding, in its spores, with the oblong ones of wheat-rust) on all the huge cotton-trees (*Populus canadensis*) growing in the American Bottom opposite St. Louis. At the period, and mostly on the day, of the leaves falling from the tree, the rust, hardly observable on the leaf before that time, at once breaks forth on the lower surface in enormous quantities, strewing its seed all over the country. I think this to be the true nestling place of the wheat-rust; its "second crop" of the year after the wheat is harvested. The rust appears in all Gramineæ in slits, or straight lines, following the interspace of veins. Following the interspace of veins, if the same rust attacks also reticular-veined leaves (as it does attack the barberry, and *vice versâ*), it must needs break forth in corresponding dots or marks (not in straight lines), on such netted leaves. As far as I have been able to ascertain from old cotton-wood leaves, that part of the rust which remains behind in the tissue afterwards produces globular sporangia with a circular opening (resembling an infusorial Arcella-shield), and is at that time replete with rust-colored fusidia (like those in the immature warts of the red-cedar galls or *podisoma juniperi*).

The famous "Oidium Tuckeri" has not yet been found destructive in America, so far as I have been able to ascertain. All common mildew, particularly that in hot-houses, where roses are raised, abound with an oidium mildew, — probably of Erysibe; perhaps, of the Yeast Fungus.

We are as yet left in the dark as to the nature of that oidium's adult stage. I have seen the zymotic mucor scantily present on grape-leaves, — not in this form, at least, a destructive disease; but then the "oidium" or the "botrytis acinorum" might belong to it.

The main point appears to be that we never raise a single healthy vine, except from the seedling. Not only is every individual plant grown from cuttings with denuded, exposed, and often mouldy surfaces, but the entire culture is a morbid one; forcing the plant to do what it naturally of course would not do; adding injury to injury, and forcing an unseasonable second growth of sickly thin sprouts, destined to fall a prey to decomposition. We actually do not know of any of our varieties, how they would, on an average, do if left to shift for themselves without any "surgical attentions" bestowed with the pruning-knife. It is thus we know of none the true, spontaneous growth; the natural season of

blooming; the age of fertility; the immunity and durability of the plant; nor even its average yield, through several years, if "good enough" was "let alone," as the case might be. We all commence wrong end foremost (which, in Latin diction, is "preposterous"), purporting to "alter" the course of nature, before we ever knew wherein it naturally consists. Without a knowledge of the normal, we cannot construe the special or the exceptional.

Having thus far specified the structural details of the Yeast Fungus, connectedly, and, so far as explored, completely, it remains, as for its morphic characteristics, to consider it in the light of (both contradistinctive and generalizing) comparison. After having thus far traced the "intrinsic" connections, — as of the species, — we may now be qualified to elicit, collatively, its "extraneous connections," or so-called generic ones, and the "natural affinities" of this fungus, generally speaking.

Considering first the adult form, — or "fruits" whereby we are to "recognize" our fungus, — the alleged genera "Hydrophora, Ascophora, Mucor, and Melidium," at least, are (with the exception of "Thelactis") for the greater part identical and truly synonymous, or represent various phases of the sporangia and "sporangioles" of the yeast, or common mould itself. The *pseudo*-genera "Azygites, Syzygites, Eurotiuum," etc., are hibernating or spawning sporangia (Dauersporen of De Bary), partly belonging to the Yeast Fungus, partly (as on roses) to Erysibe, as below detailed; sprouting into "flying spawns."

Among the species of "Mucor," in Fries's Systema, nevertheless, we find some which evidently belong neither to the yeast-plant, nor to the rest of Mucores. The (Brazilian) oblong-headed ones, or "Thelactis" of Martius, belong in all probability to the (older) gen. Phycomyces, Kunz (ibid.), characterized by its "erect-clavate, and apically umbilicate" sporangium. It has been rediscovered and redescribed as "*Achlya prolifera*," Cohn, and by Professor Leidy figured as his "Enterobryus." I have myself examined this fungus as a contagious disease upon fishes. The "fish-pest" was introduced with apparently healthy fishes, taken from a St. Louis "sink-hole" pond, by drouth reduced into an offensive mud-wallow.

The sink-hole fishes were partly dead, and covered with a dense mould, about one-half inch long: part, however, were caught moulded alive, and swimming about; while others had remained apparently intact. The latter, when introduced into an aquarium

occupied by some hitherto healthy Merrimac fishes, not only began to mould themselves, at first, all over the body; but gradually all the others perished of the same disease.

Another true Mucorine genus is evidently "Pilobolus," distinguished by its fleshy, clavate stem, and globular, apical sporangium. It is found on horsedung.

As for the alleged genus "Periconia," it actually only implied the (adult) thin-coated (immersed) sporangia "transuding their spores." They, however, are borne on the same branches with the smaller, thick-coated ones, or immersed "sporangioles." But the diagnostic determination also brings under this head, as above mentioned, the "concentric-stratified" aspergillus ("Piptocephalis Freseniana"); and (by similarity) the "confluent" aspergillus, and also the "mealy-head" confluence of the (augmented) globular-umbellate penicillium (fig. 13). Moreover, it covers all corresponding phases of similar or dissimilar fungi, and emphatically by its predicates subsumes also the entire genus "Coniocybe" of Lichens.

The same considerations apply to the floritions, or precursory, often "pencilled" forms. I have *in loco* introduced some contradistinctive descriptions of those of other fungi; and it may be proper to add that, according to Bonorden's minute researches, the basis of agaricine formations are "vast heaps of endless self-repetitions of (the corresponding) penicillia. The same formation enters into the structure of the volva; and it thence passes into the psaltered lamellæ, of which it produces the superficial stratum, in a densely connected fashion. Some of the ultimate, terminal beads swell to a pyriform shape (like an incipient 'Piptocephalis') by the way), and each extrudes the well-known four spores, each erect on a pedicel."

The "genus" Stilbum, likewise resembles, in its origin, the aspergillus, and also the genus "Calycium" of Lichens. It is found, *e. g.*, as a line-high, round-headed stubble, with an orange-colored stem and dusky, slimy, diffluent head (of erect and slim seriated beads), as the last production of some decay on melons. The "new genus Antromyces," as figured by Fresenius, evidently belongs to this genus.

In the above case, a (green) melon shows mouldy spots, of a pink color. They consist of (pink) crescental spores (as of our fig. 1), which, however, are elsewhere of an olivaceous color, being borne in great abundance on stout and short surculous mycelia

within the cells, and permeating the entire melon. It afterwards produces a tea-green, and then foxy-red "botrytis" form; followed up, on more exsiccated spots, by the "Stilbum" form. The latter, if not itself an aspergillus, at least forms the transition of that form to the Vibrisseæ, which connect directly with the agaricine fungi on one hand, and the cupulate pezizoid ones on the other.

As for the rest of (apparently adult) relations of the true Mucorines, in the first place the immersed, sebiferous sporangia of the phoma diseases must be mentioned, inclusive of the antennate mildew and the rust contagion. The "phoma" corresponds, perhaps, to the mucor, or seed-vessel; the rust to the serpentine-beaded mycelia and fingered yeast; and the antennate mildews to that of the (articulated) oidium forms of the yeast-mould.

Closely allied to the "phoma," or grape-comedo, are the genera Næmaspora, Sphæronæma, consisting, like Phoma, of single sebiferous nuclei, and Cytispora (or Massaria) with a cellular crypt, but extruding a sebaceous cirrhus, while Ceuthospora is irregularly dehiscent. Septoria and the Stilbosporeæ, likewise, may be mentioned in this connection. Such spawns, however, which take the fusidium form, will frequently occur both before and after maturity, like those of the cottonwood-rust or phoma, and the red-gum pimples (tuberculia crypts, a phase of Sphæria development). So nothing definite can be said of their nature beforehand. (Compare above Stilbum and Fusidium.) Such organs are *spermogones.*

Particular attention must here be drawn to two very prevalent types of a "mildew" with punctiform, sessile sporangia; viz., the grapnel-haired and the bulbous-stellate haired "Erysibe:" the former abundant on the live lilac and catalpa leaves; the latter, on all the mouldy live and fallen oak-leaves of vast regions in the South. In their inadult stages they form a thick-beaded "mildew" ("Oidium;" "Eurotium," when developing; "Caulogaster," when taken in connection with its bunches of entrail-like, elavate-flexuous fibrils of the mycelium). "Syzygites," Ehrb., is when certain middle joints of its crescents are thickened up into cylindric, drum-shaped, spinulose, "hibernating" sporangia, such as are likewise found on the zymotic "crescents," and figured by De Bary and Woronin, above, as a form occurring in Mucor Mucedo, the Yeast Fungus. By mistake, this has been originally construed (and afterwards so repeated on authority) as a "copulation; of clavate stubbles, arising from parallel fibres,"—these "parallel fibres" being the terminal (mucor-bearing) mycelia sprung from the

crescent. Compare De Bary and Woronin, above, tab. iv., vi., and vii.

"Azygites" also belongs here. It is represented in fig. 5, between two of the augmented crescents on the same fibre. Such terminal sporangioles are often observed, the supporting joint taking the form of an egg-saucer (altogether resembling the fruit of the sassafras). Such "Azygytes," and "Syzygites" or "hibernating-spores" (Dauersporen, De Bary), produce spawning frizzles, disintegrating into "sporidia" (De Bary), or flying spawns. In the Erysibe, they push very long and copious spiral fibrils, thus dissolved into spawning dust (always of a white color).

"Erysibe" (the seed-vessel itself) holds about one-half dozen of "asci," or sporiferous follicles; each of the latter containing, in various stages, one, two, four, or more ovoid spores. Its next ally by affinity is the sooty-looking, stuppose-haired Chætomium; resembling a sea-urchin, but only of pin-head size.* It was classed among the sebiferous-seeded fungi, but in a fresh state contains a perfect globe of radiating (incurved) "octosporous follicles," like all the disciform (Pezizeæ) and nucleolar (Sphæriaceæ) fungi, and all the Lichens. Into the latter the nucleolar and disciferous fungi make a broadside transition, by means of the rimose-dehiscent genera Opegrapha; the pedicellate Coniocybe; the candle-snuff-shaped fungoid Bæomyces roseus, the Biatoras, and the crypted (phoma-like) Verrucarias, Endocarpons, and Pertusaria lichens.

We thus can readily group the true Mucedineæ, — viz., "Mucor," the zymotic or yeast fungus; "Phycomyces," the fish-pest; and Pilobolus, the "dung-dew," and their allies, the rust and phoma diseases (as on the grape and wheat), and the smutted diseases of our cereals — into the centre of the fungous domain.

Through the minute-headed, smutted forms, such as Pilobolus, Physarum, the gelatinous-circumfused Didymium, Licea, Reticularia, and Cribrarias (the latter provided with a sort of elateres or elastic wool), they connect with the theciferous, partly "peristomiate," and radiately divided (hence musciform) group of fungi, such as the minute and rusty-woolly Arcyria, exactly shaped in likeness of a wasp's nest, on a minute scale; and originally produced on setiform stipes (like the sporangia of mosses); the likewise rust-

* See note, *sub* fig. 18. In one of its inadult stages, when produced on a stalk, it would be readily mistaken for the yellow bread-mould, but for its "areolated" surface. This stage originates from a confluent "arthrobotrys," or "copular botrytis."

colored, conical Rœstelia (the peristomiate dimples or warts, infesting the leaves of the pear-tree); while the huge Geaster, or "ground star," expands its Stapelia-like dehiscent globes (resembling dehiscent hickory-nuts) at the foot of old stumps.

The puff or smut balls (such as Lycoperdon, Bovista, Tuber, Trichia) pass into the agaricine "toad-stools," or champignons, partly by the mediation of Podaxon (a large, hooded puff-ball, permeated by a stalk, like an unexpanded toad-stool); while the forms of Stilbum and Vibrissa connect the Mucorines more directly with the Agaricinæ.

On the other hand, starting from the massive "yellow-omelette" form, strewn with grayish aspergillus dust, viz., the Mucor Mucedo, L., as found on peach-preserves (above), it connects with the frothy-smutted fungi, such as Spumaria, Æthalium, etc. (above *sub* fig. 10), which during the night appear out of very rotten stumps, the ground, etc., and occasionally alight on very different substances, *e. g.*, on a plough-share ("*Spumaria ferrincola*," *sic!*). Both these and the "smut-cap," or Phallus, which in outward form rather resembles some agarics and the Morchella, at first also has its hymenium crowded with little yellow smut-sporangia, presently dissolved into a viscid smut.

Thus the connection between the Uredineæ and Agaricinæ is complete. The latter represent the laminated or phyllodial, hence fern-like extreme, of fungous evolutions. From thence we are conducted by the carneus Cantharellus, and the evanescent Phlebia or rhizoctonium flakes, through the yellow, ligulate (or Gingko-like divided) Spathulea (truly a Cantharellus, it appears) to Sparassis, Morchella, and Tremella: that lymphatic colloid of a mesenteric form, and the phycoid extreme of fungi, which, through the *sporangioled* hymenium of Sparassis connects more directly with the forms of Pilobolus and the Mucedineæ. The gelatinous, napiform Pezizeæ again bring about a connection with the central Mucor-form, joining them with the larger disciferous or flabelliform Tremelleæ, and with the nucleolar fungi, or Sphæriaceæ (the disc becoming closed over); while the Tremelleæ, through the "scarlet root-wart," or (both sebifluous and nucleiferous) Ditiola* forms

* The structure of "*Ditiola paradoxa*" (*sic*), Fries, is not clearly understood as it appears. It forms a vermilion wart eruption on oak-roots in winter, and consists of awl-shaped and coxcombed crests, united into a tuberculous, rimose wart. A longitudinal section reveals many cysts or "spermogones," whose semi-liquid small, spore contents are profluent as the rain wastes the tops away,

their close connection with the lichenoid* Sphæriaceæ. The latter again connect backward, through Chætomium, Erysibe, Phoma, etc., etc., with the Mucedines; while having a mediating link to the gastromycetous fungi, in the shape of the pyriform — first, nucleolar, and then disciferous — Bulgaria, and the *quasi* lenticular-seeded (nuculiferous) Cyathus-chalyce, which is at first gelatinous and pyriform-closed. The latter nodulous type receives, through the asciferous cysts of Aecidieæ, its mediating connection with Peziza and the central — and, as it were, originarian — type of the Yeast Fungus, or "Mucor zymius,"† Recentiorum (derived from the Greek "zyme," the leaven of a dough).

3. *The Zymotic Agencies.*

All observers agree that in the incipient stages of fermentation, when "spontaneously" arriving, — *i. e.*, by "mere exposure to the air," so called, — the whole mass is already uniformly active by the time the smallest perceptible molecules (or vibrios) of fermentation appear. A few minimal germs, at present not recognizable as such, suffice to bring the whole into fermentation; breeding billions of rapidly travelling vibrionic molecules, in a condition which defies all detection.

As an example: a specimen of fifty-five p. c. whiskey, colored with burnt sugar, was boiled for four hours continually, at a temperature ranging between 90° and 100° C. After eight hours the residue was submitted to my examination. The colored ingredient was then found to consist, entirely and exclusively, of quite perceptible, brownish, single vibrios. The latter showed no inoscula-

opening the pores. But it seems to have been entirely overlooked, that the base at last contains large, black, corticated *asciferous* cysts, as usual with true Sphæriaceæ.

* The Lichens likewise present, beside the central, typical form of Parmeliaceæ, a fungi-form modification in the loaf-shaped Placodium; the fustose Lecanora and pezizoid Bæomyces and Calycium; and a transition in Opegrapha forms. An axiferous, foliolate, or musciform one in the Cladonias, Stereocaulous, etc. A phyllodial, pteroid one in such forms as Ramalina, Evernia, Sticta, Peltigera, and Umbilicaria. A true transition in the Fucaccæ is Collema, joining the Zorarieæ of true Algæ. A similar relation obtains in the other classes.

† "Zyme," the yeast; "kyma," the wave (crest or) scum; the Germanic "schaum," "scum," (froth), "schimmel" (dim. of scum), for mould; "kahme" (vappa), and "kamm," "comb" (a crest), are of analogous derivation.

tive tendency, the scanty supply of available matter having already been consumed in the formation of vibrios. Under a four hundred magnifying power they were found to be rather sparsely distributed, — about four to a line of apparent size in the microscopic field. This gives sixteen hundred brown-coated vibrios to a real line, no less than 4,096,000,000 to a cubic line; *i. e.*, over seven and a half billions to a single cubic inch. A little saliva was added to a specimen confined between glass slips under the microscope. They now congregated into a compact mass, having mostly run aground in the mucous matter, in the course of their travels; so that the surrounding liquid cleared up, and the mucus, densely crowded with the developing vibrios, which thus formed a compact caramel-colored cloud, could then be mechanically removed.

This explains how a piece of spoiled beef, hung through the bung-hole into a wine-barrel, troubled with refermentation, when taken out after a few hours, will thus "clarify" it, by the most comprehensive fishery on the smallest scale.

In the majority of cases, as with fermenting infusions (tea), fruit-juices, mashes or (tainted) meat, the vibrionic particles are "clear," or colorless, and hence not so easily descried as the colored ones, mentioned above, or the "black nebulæ," found on slowly decaying conferval spawns, or on floating pine-pollen. Gradually an opalescent cloud or superficial reflection, as of finely divided turpentine scums on water, — rather gelatinous or fatty-looking, — becomes apparent. After a while, under high magnifying powers, dots are distinguished. The latter are not always at first transparent, but (as frequently observed by myself, particularly in the case of decaying confervæ or the pollen of pine-trees above mentioned) of a sooty black color. The latter kind of dots, considerably less than $\frac{1}{4000}$ of line in diameter, are observable as a dusky mass or haze, accumulated around the confines of such pollen or conferval fibres, so as to present the appearance of a dark or black "indissoluble nebula," — composed of individual elements no longer recognizable under a six hundred magnifying power. Gradually increasing in size, they likewise become clear, and also individually distinguishable, as vibrionic, agitated, saltatory molecules. When at about $\frac{1}{3000}$ of a line, they assume a confine, and then directly lengthen into fibres of the same calibre, which, as above detailed, either swell into yeast, or lengthen out into leptomitus. This is the average calibre of the finest fungous tissues; *e. g.*, where the corruption in dead or living wood penetrates in a

compact form, with the well-known black enveloping (or advance) *sheet.* This appears in a section as a black vein or marbling; resorbing, in its rear, its own fibres as it advances, invading the sound wood-cells. These it substantially fills, exhausting their tissues; leaving them (in the rotten part) behind empty, and enclosed roundabout within this enveloping "hypothallus," or front line, which is often found doubled back upon itself as carried by the accidental moisture, etc. In the case of the verdigris *Peziza æruginea,* — often found on red-oak wood, — its dark green color penetrates far ahead, without a confine, into the apparently healthy wood; while yet no distinct individual fungous particles are discernible with the strongest magnifying powers. It hence follows that the fungous agent is there prior to the "decay," and, *cæteris paribus,* the (distinctive) "cause" of it; and, also, that the first invasive fungous agent is not always discernible with our present microscopic powers.

The fermentic dots (and similar ones of other fungi) appearing uniformly by the billions at once, no clew as to their origin was given, until the late discovery of the "nebular exudation of germ-life" from the smallest fungous fragments (*sub* fig. 8) was made. The minuteness of these final, constitutive particles fully coincides with that of the fermentic inchoative form; being so minute that, upon the mere surface of the smallest fog-vesicle visible at ten inches' distance, fully a million of independent fungous integrals might find accommodation, whether such germs be of a single or of a million of different species. The "spontaneous" origin of fermentative accidents can thus very readily be accounted for in any pendant case on record. Of course the application to infectious epidemic diseases is tangible. For aught we know, their multifarious "germs" (if of a parasitical nature at all, and not dependent on mere physical or dynamic circumstances) might be ubiquitously present, ready to seize on a constitution susceptible of their parasitic action, if so be.

The ultimate, subtle, and thenceforward inscrutable suspension of organic germs is here evidently the main point. The nature and existence of neither the pulverulent (vibrionic) chalk-white,* pruinose (moss) efflorescence from clay in spring, nor of the spawning frizzles, and the still more infinitesimal, nebular germ-

* "All clay or earth, — even when only recently dug up from pits or excavations, no less than every surface crumb of soil, — after snow frost, and then on drying up, will be found sprinkled with an efflorescent, white, subtle, incrusta-

effusion in fungi, had as yet been ascertained. This being known and re-observed thousands of times, there is no longer any occasion for supposing a "generation" (*sic*) without a generator or germ.

Let us here, for an example, consider the ferment of the main river of our country, the dusky-flooded Mississippi. The old St. Louis city reservoir contained the supply of water for about twenty-four to thirty hours. The water was thus left essentially unaltered, such as it was gotten, and passed through rapidly, being speedily transmitted to the hydrants. In the reservoir the water stood about twelve feet deep, rather accurately even-floored, as a late accident revealed; all the remaining depth of reservoir having been filled up by the growing deposit of a fine, gritty, grayish sand: after drying, barely cemented, and by the slightest pressure at once crumbling into the finest quicksand. There is hardly any other "impurity" contained in this material, which readily subsides, after a perfect rest of about twelve hours in a barrel. There remains, however, in the water, an opalescent (pale, milky-hued) "enaiorema" or innatant ingredient, of which in hot weather a great percentage rises and collects at the surface (*e. g.*, of a barrel) in the shape of a gelatinous cloud, one-quarter to one-half inch thick, in from one to several days. This cloud was almost entirely and uniformly composed of dark, brittlish, meandering, and half macerated fungous fibrils, about half as thick as a cotton fibre.

tion, resembling snow or sugar thinly strewn. On marshy or manured places it acquires a conspicuous luxuriance; *e. g.*, near dunghills, etc. The same is found efflorescent on well kept flower-pots in hot-houses, on the very crockery; forming snowy designs like lichens or clouds, which — on repeated percolation from the inside, and in that atmosphere — are soon followed up by all subsequent stages of moss vegetation, acquired in such favorable localities; such as a bright green, or a dark green ('ulvaceous,' 'chlorococcus,' and 'oscillarious') coat, followed by that beautiful minute and sap-green velvet, which is subsequently found budding the leaved stems of various true mosses (mostly of *Bryum argenteum*). When thus efflorescent, like a dry white-frost, a little moisture will convert its truly impalpable and immeasurably fine germinal foment — like the inchoative ferment-nebulæ — into a sort of gum, percolating all soils and streams. In such positions as leave the surface entire, — *e. g.*, on embankments sheltered from abrasion, — it is then again efflorescent as a dry, white incrustation, which toward the moister places is seen growing, first, into a gelatinous-crumbed, brownish meal, rapidly converted into glairy, vivid green 'ulva.' The latter, turning of a lustrous blackish-green (oscillaria) color, subsequently produces the buds of bryoid, true moss, with (or without) its soft green velvet tapestry (or 'rhizoclonium,' etc.) from 'gloeocapsa'-cells." — *St. Louis Medical Reporter*, Jan. 1, 1867.

Such fibrils are constantly exuding a fungous "nebular" haze of frothy cream, which has sometimes been seen by myself visibly spouting forth from the hydrants, and filling the air with offensive gases, priorily compressed within the pipe. Where a sufficient amount of new aliment — *e. g.*, a little piece of glue — was supplied, this "haze" or "aura" attained a great luxuriance, and within forty-eight hours I have seen all the glue and molecular froth together converted into a dense "leptomitus."

The floating swamp-productions, — *e. g.*, the oscillaria moss-spawns, — forming in summer dense "rugs" along the sides and over the entire bottom of sluggish streams, and incessantly buoyed up by the gases generated, carry an immense amount of gelatinous deliquescent, corruptible matter into the turbid river. The dark, deep, and turbulent river is, of course, unfavorable to the development or even preservation of such spawns, which are reduced to their subtlest germs; while the greater amount of their gelatine falls a prey to a sort of gangrenous corruption. It is evident that in the river the greater amount of corruptible matter is already completely decayed, and converted into the finest fermentic germs, ready to infect at once any suitable substance offered. They evidently come into account almost exclusively for the enormous amount of "albuminoid" matter — whether animal or vegetable — shown to exist in the water by the following experiments.

Not many years since a prominent drug-store of St. Louis, Mo., largely engaged in chemical manufactures, in order to test the availability of the water as to freedom from corruptible substances, had a glazed settling-urn, in a cellar, filled with previously decanted hydrant water, and carefully covered. There was very little of earthy sediment present, but the "opalescent" impurity (mentioned in the "First Report St. Louis Water Commissioners," 1865, p. 25) was, of course, not removed. After a few weeks the water appeared clear, at first sight; but in the throat of the urn, about one-third of its diameter, a compact ledge, averaging one-half inch thickness, of a perfectly transparent "leptomitus" jelly, was found. It was itself altogether inodorous, all corruptible substances having been consumed by it; and I found that it consisted entirely of the finest fungous fibrils, closely packed; two thousand side by side to each line, four millions to a square line. Most of them being in a process of transversal self-division into globules of like diameter, it afforded as many as the cube of two thousand; *i. e.*, eight thousand millions of individual and well-defined, cellu-

lar, septic germs to the cubic line. No adequate sanitary analysis of the Mississippi water, at St. Louis, having ever been undertaken by the metropolitan water-work commissioners, this palpable neglect was in part redeemed through the unrepaid services of Dr. Theodore Weiss. Several analyses were made by him of water drawn from the hydrants at different seasons, and at different times of the day; those of four specimens taken at different parts and depths of the reservoir; and several from the surface of the river. One was independently executed for me by Professor A. Wadgymar. All analyses concurred in this startling result, that in summer the hydrant water contained, on an average, six grains of exsiccated mucilaginous substances to each pint of drinking water. Of this enormous percentage, partly of fungous fibrils, grown of a corruption already gone through, one-half remained on the chemist's filter, while one-half passed it (three grains) in a soluble form.

The results obtained from a specimen taken at the upper ferry, midway in the river, where the waters of the North Mississippi River and Missouri are commingling, showed the gritty mineral deposit to be only one-tenth, and the organic percentage one-third, of the above average. At the time of the late cholera visitation, the untiring attention and efficient action of the Board of Health revealed the fact, that in course of time the offal of no less than twelve butcheries was being discharged into the river above the spot where the suction-pipe was located, close to the bank, in shallow water. The effect of the immense amount of garbage thrown into the river at St. Louis is such, that the water taken in July, about six feet out from the bank, at Sulphur Spring Station (about twenty miles south of St. Louis), was found undrinkable on account of its cadaverous taste, or perceptible "taint."

Water drawn directly from the hydrants, unless cooled down to a frosty temperature (by melting ice, whereby the fermentic property is momentarily checked, and so much pure water added), affects the stomach at once with a nauseating disrelish, — a "sickening," or at least "unsatisfactory" effect, actually preventing the slaking of thirst, as required; while cistern water, or that derived from ice itself, is imbibed with a relish, even if at a lukewarm temperature.

In a like manner, air, when imbued with disease, malaria, effluvia, or unknown noxious agents (*e. g.*, at times when cholera is epidemic) seems "oppressive," not affording any of the bracing

effect of "pure" air; *i. e.*, air which is relishable. In both cases the "bracing quality" is very sensibly appreciated as such, but by no means necessarily as a "taste,"—whether a true (glossopharyngeal) savor or a "flavor;" *i. e.*, an odor internally experienced in the conchæ on deglutition.* Speak of "healthy water," if it does not exactly smell! Why not speak of "healthy" carbonic oxyd, for respiration? It has no perceptible odor; although it is not only unfit for respiration, like nitrogen gas, but a positive poison. Yet it is neither smelt nor tasted.

Another evil, resulting from insensible but widely diffused corruptive processes, affects such seaports as are placed at the mouths of rivers emptying into the sea. The brackish or salt-water, obtained from East River, New York, and sent west to serve for marine aquaria, was, on inspection, found thoroughly clouded with large "cirrhi" of mycoderm; and the yeast-fungus was found sprouting its pale penicillium and exserted oidium-joints on any solid floating substance. This may simply have resulted from impurities incident to ports as such,—witness that of the city of Marseilles. In a great measure, however, the tidal alternation, by backing up of rear-waters, and a subsequent increased rush into the sea; but, above all, the mere fact of the river discharging its fresh-water life into salt-water, and *vice versa*, must necessarily cause a constant destruction of fresh-water life on the one hand, and of marine life on the other. In one respect the river serves as a sewer, in the other as a source of littoral life-destruction. In the latter respect the mangrove coasts of tropical climates may be mentioned as a never-failing source of malignant effluvia.

A most remarkable and significant feature in the manifestations of the yeast-fungus, as a corruptive, is that, although it is seen to freely decompose (and nestle upon) other fungi, it remains itself apparently unaffected by such agents; or, at any rate, if effete, it will, like all other substances suitable to furnish life-material to the yeast-plants, primarily fall a prey to its own latent germs, or to the omnipresent ones of its own kind. This has given rise to a foregone conclusion that the "oidium lactis" and "mucor" were final evolutions of all (effete) fungi.

It is this truly universal leaven of nature that not only ferments our best victuals: the bread; the wine; beer, cider, milk, cream,

* See "Experimental Observations on Taste and Smell," Proceed. A. A. A. S., 1854, p. 256. Also, "Vindication of American Priority," St. Louis Medical Reporter, Jan. 1, 1868, p. 644.

cheese, and curds; the vinegar; greens, krout, and pickles — but likewise demonstrably effects the putrid decomposition of all human flesh * and human diet ingredients, — of waters, garbage, carrion, and contents of the water-closet. It thus becomes the natural or *normal corruptive agent* of all our "normal" as well as "morbid" body constituents and secretions; of all our healthy as well as abnormal stools and offal, without exception, so far as examination has ever extended.

It is this fungus which likewise consumes the gelatinous, and often very massive ("confervaceous," "protococcus," and so-called "palmellaceous" paludal and uliginous) bryaceous spawns of all soils and bogs, of rivulets, rivers, swamps, and shores.

It is thus universally productive of pernicious and (in a concentrated form) offensive and essentially "gangrenous" effluvia, which, in a dilute condition, are mostly recognizable only as a mawkish "flat" (or swamp) odor. Essentially of the same nature are the dreaded "stinking fogs" or odors, whether originating from putrescent aquaria, from slaughter-houses, or from river-sloughs, swamps, and bottom-lands. These exhalations (recognized by a sort of "burnt kid" leather smell) are as distinctly felt as they are deservedly reputed to be directly productive of the malignant swamp-fevers and "congestive chills," both in the lands surrounding the "Putrid Sea" (Seewah) of Crimea,† and in the redoubtable Taraï bogs, at the foot of the Himalayas. The same probably applies to all the extent of malarious flats which follow the abrupt southern declivities of the line of alpine elevations from the Pyrenees to the Himalayas, such as the valleys of the Ebro, the Rhone, Po, Kuban, Ganges, etc., and to all other malarious plains.

From its known abodes, its sufficiently well-known action, and the asphyxiating (perhaps desozonizing) influence of its nitrogenic effluvia upon the atmosphere upon which our very "breath of life" or of death depends, this fungus — a constant *irritamentum malorum*, as well as the active principle of benign fermentic energies — may, of all, lay a prior and sweeping claim to the title *par excellence* of the "Zymotic Fungus." The study of its processes

* As above (compare fig. 8) observed, the muscular fibre in the process of putrescence seems to dissolve substantially into the sarcode vibrios. The latter, judging from Liebig's latest analyses of the "active yeast ingredient," have the identical chemical composition as the flesh.

† St. Louis Medical Reporter, Jan. 1, 1867, pp. 526, 527.

affords not only the most comprehensive analogies to the formation of all organic cells, but also to the vital "assimilative," and hence "specific" creative functions of every other organism; with this advantage for study, that in such elementary structures the processes of life are laid open to inspection *in vivo*.

As for its influence on morbid phenomena, its action may be rather estimated, than it can at present be determined, by the comparison with the action of such fungi as, being parasitic on certain trees and their leaves, take a luxuriant growth also in the masticated fragments of the same leaves, within the body of the caterpillar, which feeds on it, as in the case of the Muscardine. The lymph and blood, containing such aliments, likewise become demonstrably affected, and charged with the visible (orange) vibrios of the fungus; and in the case above quoted (Pasteur's discovery) this even extends to the eggs of the hatched (but diseased) moth of the silk-worm.

It is, however, but too true that the crowd of supposed "specific vegetable parasites," lately claimed as the specific virus of several dozen diseases, — from the diarrhœa to the hydrophobia (!) — are only fragmentary forms of the inevitable decay, and neither show any mutually "distinctive (specific) characters" whatever, nor have they been bred into any thing like a mature condition. Surprising as the fact may appear, the vicious circle which binds together those alleged discoveries simply amounts to this, that it was taken for granted, *a priori*, that contagious diseases must be "fungine parasites," on account of the resemblance between them and the true fermentic phenomena; oblivious of the fact that all normal regenerative life, above all, is itself of an essentially "reproductive" nature. Several morbid functions (or "diseases") being "specific" (as all our *normal* functions * emphatically are), some specific fungus was to be made responsible for it; and whenever an incipient fungous development was found in the

* In their own "vernacular," this school might be answered that, seeing the functions of the body are specific, of course every man must be his own fungus! We have lately seen proclaimed, among the great number of "new specific fungi," such genera and species as "*Crypta syphilitica*, *C. gonorrhoica*, etc., Salisb.," the débris of the spiral elastic fibre of human anatomy, as found in old destructive ulcers (vomicæ; L. Beale) likewise. A species, without a cell or diversified structure; without organs, growth, or development; without a Natural Kingdom, but that of ("bad") names; no plant; no animal; no life, — but a ruin; truly a "fungus a non fungendo."

rapid natural decay of any morbid secretions, it was at once hailed as the (supposed) "specific" fungus; no rational comparison being instituted for the inevitably arriving, *normal* fungous decay. The literature on this subject exhibits not a single experiment upon the nature of natural cadaverous corruption; and this shows the entire want of discriminative comparison, whether between the normal and supposed abnormal, or between the supposed "specific" organisms, mutually and respectively. We cannot, however, pronounce upon the special, morbid or peculiar characteristic, before having compared it with the normal, healthy or general; nor can we distinctly "classify" things, unless we are acquainted with their nature, connectedly, completely, and distinctively (or "comparatively").*

It is the old and well-known "oidium lactis" form which has lately been detected on choleratic discharges after a week's putrefaction (!), and hence construed into a bran-new genus, and claimed as a "specific parasite," although neither new nor unknown, nor exotic, nor in any wise a *distinctive* feature. This famous "*Cylindrotænium choleræ indicæ*," *sibi*, *Thomé*, or *oidium lactis*, forms, by the way, the only healthy or eatable phase known of the yeast-fungus; since it substantially composes the rind of the justly esteemed clabber cheese.

It is thus that this our innocent household benefactor has been feloniously caluminated, and also officially acted upon by the British Government; purporting to have it hunted up in its "native haunts, in the rear jungles of India," as will be well and long remembered.†

Our epidemic anxieties, and the ruling passion of our betters, have always exercised no little influence on the "customs" of the period, variously taxing the devices of ingenuity. A short time ago, when "specific fungi" were all the rage, and were being brought in, daily almost, some professional friends of my acquaint-

* The nature of things, as the Latin word itself (*natura*, from *nasci*) emphatically implies, consists in their genesis. The understood causes cover all the "consequences" or ultimate, complicated phenomena which thence genetically arrive. Mathematical logic consists in the generation of ultimates from principles; Physics, in that of effects, out of causes; Biology, in the knowledge of the origin, development, and end (reproducing its own vital factor), as for living things ("beings," or "essences"). Mathematics is the quantitative, Physics the qualitative analysis of Natural Phenomena.

† See Hallier, "Die Cholera-Forschungen der Englaender in Ost-Indien." [P. S.] Comp. Dr. Lewis: 6th Ann. Rep. Sanit. Comm. Gov. Ind., p. 140, bel.

ance, on meeting in the streets, would no longer inquire, — in the spirit of ages, now among the past, — How is your bank? or, How are you, conscript? but with a conscious wink about the eye were heard to suggest, How is your fungus?

For should it not be truly painful to reflect that any healthy man should not only be found "blooming" with the scourge of our potato-fields ("*oidium violaceum*," Schacht, fig 6, of our plate); but in his healthy stools be considered fraught with the dire "Cholera-fungus; fructifying only in India," on eminent European authority! Must not any healthy and well-informed citizen appear to himself like a walking infirmary; an object of just suspicion to any properly organized board of health? Might not such a *misérable* feel committed like the Member of Parliament, who lately confessed to having had the rinderpest "himself"? Still, such are actually the grave complications arising where the unhurt receiver and dispenser of the omnipresent germ, which breeds poison under slightly altered circumstances (in the heat, the swamp, the water-closet, and the sewer), is crowded upon his fellow-man. Hence the "sewage question" — the sanitary question of the day — is emphatically one of the yeast or corruptive fungus, which has no corruption greater than itself. The great ultimate development of Rome, as a fortified city of rapine, it is true, but also of civic order,* was indubitably partly due to its "*cloaca maxima*," built by the Proud Tarquin: the fundamental ditch-maker of the Eternal City.

The want of drainage is, indeed, the "dead" point of all metropolitan development of small places, and remains the vital question of two of the largest commercial cities at the most northerly and the most southern extremity of the Mississippi Valley, Chicago and New Orleans.

Above a temperature of about $+16^{\circ}$ C., the highly salutary, lactic fermentation of all dairy produce — of milk, butter-milk, butter, cheese, and cream — is rapidly changed into the horribly offensive butyric one; *e. g.*, where milk or slops remain stagnant in sewers, or in the pestiferous slop-puddles forming near farm dwellings. It gives the full clew to the sanitary economy of those reputed ancient lacustrine city-builders, already known to Tacitus; †

* Hence the term "civilization." How it operated, see Acts xxii. 25–30, xvi. 37–39. It is the main key to Roman successes.

† Tacit. De Germania, cap. xliv. Suiones; Svenske, the Swedes, who at home dwelt in the Swedish inland-seas, and, it is well known, in the great migration of

and the descendants of whose neighbors also retained their ancient vernacular in the name of a city famous for its natural sewers, that of "Venedi," or Venice.

The Zymotic Fungus being the uniform ferment — yeast and corruptive — of both the aliments and the flesh and secretions of the human body, it must necessarily exercise certain typical, if not specifically infectorious influences on that organism. Its forms and functions, *vis* and *virus*, are no less diversified than those of the most complex organization, — that of man, itself. It must also here be repeated that the fungus "reproduces" its special phases; and consequently the "specific energies" thereto belonging, severally and respectively, so long as the nurturing material and other physical conditions remain the same. It also persists in reproducing the previous type by preference; thus, for example, transferring the *oidium-monilioides* production of the rotten cabbage to the apple (*sub* fig. 2), which from its own primary fermentation (starting from its acido-saccharine ingredients) only moulds with the "*penicillium glaucum*." The mucor phase is much more apt to reproduce mucor forms directly from its own (*uredo*) spores, rather than penicillia; and the latter rather repeat their own form, for which the elaborated cell-contents are once adapted, than a higher, progressive one. It is thus that an "intensified," or special poison can, under special circumstances, be produced and rendered self-reproductive out of an organism innocuous under different ones; and that to either utilize or to resist, our economy must be specially adapted, or it must perish in a short time. The universality, the beneficency, and the pervertibility seem to be equally shared by man and by that "corruption": in the likeness of which our flesh and sarcode is "sown" (or spermatically vibrionized), in the entire developmental and regenerative processes no less than in the reproductive ones.

The chemical consideration of fermentic phenomena has hitherto only been cultivated from the points of view offered by the material,* which serves for the development of the yeast-vibrio. The

nations, — caused by sudden arctic refrigeration in both continents, — pushed also into Switzerland (which thence derives its name, "Shvytz"-"Suecia"). His "Venedi," or Vends, cap. xlvi., afterwards built Venice.

* The multifarious action of the vibrio in producing the alcoholic, lactic, and putrid decomposition, has been repeatedly emphasized. The biological relations, however, being our present subject, the chemical detail of its effete educts can be left to the chemical operator.

latter itself, however, has been abundantly confused with certain molecular animal phenomena which I have detailed in another place (*Jour. Sc.*, July, 1871); and vibrionic inosculation has *e. g.* been described (in the symbolic language of "animalism, and its cannibalism") as "serpents snapping up vibrios." The genus of reptile not having been specified in such cases, we are free to presume that it belongs to the class which, "more subtle than any animal — made" (*i. e.*, arrived at the adult state), corrupts the sources whence we draw our life.

As a latent germ of disease, it partakes certainly of the virulence both of the snake and of "the leaven of corruption." It is in this sense that particular attention is called to its partial existence as a parasite on human secretions (*penicillium hominis*) within the ear, etc.; the full development and nature of none of the actual fungous parasites on the human body being as yet studied to the end. I here refer to the scall, or ringworm; the *herpes decalvans*, *pityriasis versicolor*, etc.

It is thus that particular interest attaches to the study not only of all its possible forms and phases, its conditional fermentic — alcoholic, vinous, lactic, acetic, butyric, etc. — and corruptive capacities, but also of its adaptability to act as a morbid agent. In this respect the comparison with actual contagion through fungous agencies becomes momentous; and reference has already (above) been made to the well-established case of the Muscardine.

An analogous process has lately been observed by Professor Hallier on a fungous disease of pines: the "botrytis" state of a Fumago (a perfect or adult fungine form, incident to willows, etc.). It also attacks the pine-leaf, and also "ferments" (in its way) the bowel-contents of the ravaging caterpillar, which of course must perish. The fungus, as a matter of course, finds its way to the surface, and doubtless also infects part of the chyle, lymph, and "blood" of the insect. The simultaneous appearance of Mucor Mucedo on the surface, by no means, however, argues a vital identity between it and the "Botrytis Fumago," Fries. The larva died. It will decay; if not by the "botrytis" of the tree, it must decay on some other fungus; and here we find the Zymotic Fungus represented in the drawing by Professor E. Hallier. This alone, however, cannot by any means justify his assumption of the Mucor being a "cell-formation common to all fungi," as he would seem inclined to let it appear.

Another case, which has excited attention, is the frequent

occurrence of the "*Cordiceps militaris*" on dead June-bug grubs It consists of one or two slender horns, like an antelope's, projecting one and one-half inches out of the dead larvæ. "What is it?" we ask ourselves. Why, first, it is a dead grub; second, it is consumed by a fungus. Reason says at once (1) grubs will sometimes die; (2) they will then inevitably be eaten up, either by animals or by some corruptive decay. Next: What did they die of?. Anxiety suggests, by "contagion." Reason inquires about the indispensable —

"Quis, quid, ubi; quibus auxiliis; cur, quomodo, quando?"

Who gave it? who found it? where, when, and how?. The careful and explicit evidence soon reveals the fact that the grub is found in turf lately ploughed up. The grub fed on the roots of the grass. The grass was killed by the plough. What became of the grub? Bad fare killed it. At all events it could not live thus any longer. Now all these connected natural circumstances fully explain that the grub had to die. We have, therefore, no further reason to suppose any other cause, this being sufficient to cover the case. Now, as for the second part, — namely, respecting the nature of its decay, — the common (normal) fungous decay of dead grubs is not known to us at present. It may derive its germ from the air, the soil, or the dead putrid grass-roots; but it is not the decay of the human body; and it need not be, perhaps. Still, all this does not exclude the possibility of some "diphtherous fungus of grubs, growing out of the salivary glands" of the same. Only the worm died, and was consumed. The decay probably proceeded from the bowels' contents, which were themselves partly derived from decaying roots. The fungus completely stuffs the body, substantially, with its own uniform, whitish, gristly mass, consuming all except the horny body constituents.*

* The top of the horns (when bred in wet soil under cover) produces a cob or spike of close-set nuclei, replete with slender slivers representing long, thin, filiform wires, of snowy whiteness, that spontaneously cross-divide into globular granules. These again form into chalk-white fungilli, in form resembling a candle snuff; and the whole stem and grub produce similar ones from every lesion, as well as spontaneously, — a sort of *torula*, acc. to Tulasne. If not *asci*, the slivers may be *spermogonia* for the Cordiceps; what the red gum-pimples (Tubercularia) of oak-branches are to the nucleolar *Sphæria effusa* (or "black-enamel slag") of the trunk; and what the sebifluous apical cysts of *Ditiola paradoxa* (the vermilion root-wart) are to its inferior hidden sphæriaceous cysts or nuclei, all on one warty convolute.

Again, all dynamic, chemical, botanical, and zoölogical forms and constituents, as well as functions, being specific, — morbid processes, in the great generality of cases (excluding surgical ones), cannot anywise help being likewise more or less specific. For a specific process it only requires one thing to be *sui generis;* and such, first of all, is the body itself.

Now, as to "contagion," we ought never to forget that the body is built up of tissue elements, which are not only reproduced by the generative processes proper, but also by way of internal regenerative restitution. Propagation and regeneration in the case of the yeast, as in all others likewise, are at the bottom of contagion; but, we may ask, how is it effected?

The whole system of life is an ocean of reproduction of its own normal constituents. The latter are partly, as in plants, "built up" one upon another; partly, as in animals, used up and replaced *in loco*, thus rendering an alternation of substance ("Stoffwechsel") by local restitution, a purely animal peculiarity. It is thus that, by a continual typical reproduction within itself, the animal fabric is sustained. How if it should sometimes reproduce typically, but perversely, so? It certainly "fructifies" regeneratively within itself; and reproductively in the sexual processes, rebuilding another complete body out of very few vibrionic factors. Should it not sometimes morbidly, perversely, and *de*-structively affect "another body," by such agencies as, *e. g.*, its own normally disintegrative factors having taken hold of the "regenerative functions"? In remoulting, are there not also constantly decomposing — not only the remoulding and remodelling — agencies at work?

As for the morphological agent concerned alike in all these cases, the normal (bi-sexual) animal propagation* is enacted by the seminal vibrios (a sort of "Flagellate Infusoria," of certain classifications). They previously constituted the "nucleus" of spermatic cells.

A parallel is afforded in vegetable pollen-fructification, in the case of the common flowering moss, or *Portulacca grandiflora.* When

* Comparatively speaking, perfect flowers are unisexual, or true (monoschematic) hermaphrodites. The fertile animal system is bi-sexual, being *di*-schematic, even in its apparent hermaphrodites; such as snails. The glandular organ of the latter secretes, first, the seminal cells; and then, likewise, the ovum! The anther corresponds morphologically to both the animal ovary *and* the testes. Monœcians are "mutilated" monoschematics; each flower being *semi*-sexual.

touched by the apex of a stigmatic papilla, each pollen-grain is seen to liquefy locally, and to disgorge a thickish stream of large individual vibrios, not enclosed in a hose, or "fovilla," but freely and independently moving across and against the main stream and against each other. The well-known case of Asclepiadeæ is very different, where the conglutinated pollen-cells develop a long discharging hose, which of course remains behind empty, like the pollen-membrane itself, as in the case of Orchids.

Other animal and vegetable cells likewise have a nucleus or two, constituted of movable vibrionic particles, which divide apart and course about, in the process of cell-division, or, as chlorophyl-granules, stream toward the light (as in young moss-leaves), and retire on its cessation. They also leave the mother-cells, and originate new net-works of vivid green cells around the empty ones in the development of certain moss-leaves (*Bryum argenteum*). The fact is, that the so-called "rotation of protoplasm" is actually an intra-cellular circulation of vibrionic particles. In the case of Chara, Anacharis, Tradescantia,* Closterium † (not an animal, but, like all Desmidiacea, a bryaceous spawn), it is as clearly observable as in the hitherto apocryphal "amœba" dissolution of the *Vorticello-Planarian vitelli*, hereafter to be detailed.

In Closterium, the red rosetted "eye," or cell-nucleus, at either extremity, represents a globular cavum (filled with liquid), in which about a dozen of individual vibrios are seen swaying to and fro, and coursing within the cell, entering and leaving as in a bee-hive. Their bodies are clear, and the ruby color is owing exclusively to the flashing of an otherwise indistinct appendage.

Likewise, the large, green, peristaltic-writhing and flagellate protoplasm-sarcode, called Euglena,‡ which covers still pools with the bright-green scums, is the analogue of a "spermatic" element, notwithstanding its huge size. It occasionally dissolves into vibrionic elements (each again a minimal "flagellate infusorium"), ready to develop into an oscillaria fibril (a bryaceous spawn); or, in case of the "encystment" of the "Euglena" sarcode-body, this false flagellate infusorium (*ut habent*) casts a tap-root, and grows

* Comp. Carpenter, The Microscope, etc., §§ 216 and 246–248.

† Ibid., §§ 178, 179; St. Louis Medical Reporter, Jan. 1, 1867, p. 518.

‡ Ehrenberg, in Trans. Berlin Acad. Sci., 1831, Tab. I.; ibid., 1838, Tab. VI. figs. 7 and 8. The flagelli are not figured, notwithstanding their length more than equals that of the body. A five hundred magnifying power is hardly sufficient to detect them. St. Louis Medical Reporter, Jan. 1, 1867, pp. 520, 521.

into a moss. The "filiferous capsules"* of low animal organisms likewise exhibit, in their retractile "nettling" hair, the highly compound structure of such flagellatory organs on the animal, as we find it also observably demonstrated in the case of the bryaceous "euglena" sarcode. The latter, when enclosed in the dark, and without soil, is seen developing its chlorophylline component particles into a mass of only loosely connected, and afterwards liberated individual vibrios, resembling those of the "red eye" of Closterium, and also those of fermentation, so as to be no longer distinguishable *inter se.*

"Closterium" is in part produced directly by the encystment of "Euglena," together with the spirally denticulated "*E. Pyrum*," Ehrb., and wafer-shaped, caudate "*E. longicauda*," Ehrb.,† thus transformed; *e. g.*, on a China saucer or a glass slide. When dissolving into clear vibrios, however, the porrected and thickened flagellum is shed, and, on the glass slide, segmented into silicious (or so-called Navicula) joints, which individually develop onward. Hence it is probable that the organization of the flagellatory organs is a very compound one, although in most cases almost entirely escaping the highest microscopic powers, and, in the case of the Closterium "eye," rendered recognizable only by its red color. It is thither that the further researches of microscopic physiology have to be, above all, directed; and increased powers of discrimination here become highly desirable.

One of the manifold originations of the euglena-sarcode itself, which I have fully observed, and in part communicated ‡ before now, serves to throw some light on the action of spermatoid vibrios, of the smallest calibre ($\frac{1}{2000}$ line, at best), as the agent of the pre-cellular developmental genesis of tissue-elements.

"Where oscillaria-coats, constituting the blackish verdigris lubricity on fetid pools (as well as on wet shady grounds), § leave openings on the surface, a thin film of the 'peristaltic' euglena-sarcode is found. These bodies are partly 'red-eyed' or 'fully developed Euglena;' partly green all over their surface, and of smaller size (Cryptomonas). Among them are found a great number of smaller, dark-green, globular yolks, endowed with a large hyaline 'albumen' coat, evidently the increased segments of 'gloeocapsa' of oscillaria.

* Carpenter, Microscope, § 338.

† These are figured as supposed "animals" in Trans. Berlin Acad. Sci., 1831. Tab. I.

‡ St. Louis Medical Reporter (above), p. 525. § Ibid., pp. 515, 516.

"These at first remain perfectly still, until one of the vividly swarming, minimal hyaline vibrios is seen seizing hold upon, and vehemently hustling round, such (otherwise inert) yolks; apparently 'attacking' the circumference of the albumen as by a flagellum, and gradually disappearing inside. . . .

"As the vibrio, penetrating, is lost to view in the profile, the 'gloeocapsal' yolk again becomes quiet, until, after a few moments, all at once the granular chlorophyl-particles, constituting the yolk, manifest a great commotion, and, as if liberated, are seen as so many individual green vibrios. Segregatively thrusting themselves into the surrounding albumen zone, they now inhere under its surface; whereupon the green body now becomes a 'Cryptomonas' or juvenile 'Euglena;' commences, slowly at first, to contract and writhe as a true (low-sized) peristaltic-sarcode cell of that scum."*

As above remarked, the Euglena can encyst into Closterium, which again breeds into various desultory forms; or the Euglena takes root, sprouting a "rhizoclonium" moss-velvet, which bears the juvenile moss-bud.†

In view of these well-observed facts, "there can be now no longer any doubt that, as the vibratile epithelia of the intestine flicker, so certain intertextile cell-molecules, and not only the true so-called spermatozoa, are endowed with a vivifying, promulgatory, motile agency of cell-life; the regenerative, if not alike the reproductive element, or true 'vital' phenomenon."

There is also ample evidence to assume that all the circulatory vibrios, those enclosed within the fibre (fig. 5) as well as the free fermentic ones (fig. 8), with the yeast-fungus, as with all other observed organisms (including those of the "germinal matter" and of the immature and transuding blood-corpuscles), are all alike endowed with a flagellatory organ, resembling in structure that of spermatic cell-nuclei (or spermatozoa), "exciting" themselves, as it were, on the "waters of life."

The same applies to the erroneously so-called "androspores," and to the minimal vibrios of other intertextile processes, as represented in a subsequent paper on the titular genera of so-called fresh-water algæ, as bryaceous spawn developments.

The same also applies to the vital vibration of some invisible flagellatory organs, active upon the surface of the assimilative and

* The perfected "closterial" as well as "Euglena" phases extrude fæces-like, vibrionic spawns.

† St. Louis Medical Reporter, pp. 516, 521, and 522.

bronchial membranes; *e. g.*, of live tad-poles; and of the mollusks,* where they are said to be distinctly recognizable.

The fact that they are often indistinguishable in the dead is partly owing to the cessation of action, and to their natural minuteness; but it allows also of the supposition of retractibility, as in "filiferous capsules;" or, of being dropped, like that of "Euglena" (above); and such might also be one of their normal functions, by the way.

The ashes of the "Closterium" vibrios leave a silicious (insoluble) residue; hence the vibrio assimilated silicious combinations, which, as apparently pure silica-coats, are left as educts; *e. g.*, of the "naviculæ" spawns, etc.

The independent vitality of certain detached flagelli, as well as the phenomena of "spicular" prolapse (mentioned in the chapters on yeast and the peach-rot), make it plausible that in certain cases the fragments of the flagellatory organ of vibrios, themselves but just visible under the highest powers, may be endowed with the "promulgatory" action of cell-life, whether diseased or healthy. Sufficient analogies of the endurance of molecular-life are given, and partly laid down, in a succeeding paper on the "Circuits of Generation of Molecular Animals." In this shape, where a considerable degree of exsiccation is endured, germs not only of "parasites," but perhaps also of individual, morbid activity, might easily be conveyed by the arising vapors; but, above all, by the active pulmonary exhalation of diseased individuals; as is probably the case with the rinderpest, and most exanthematic diseases; and in fetid bilious derangements, perceptibly so.

The discussion of morbid phenomena, from a technical point of view, being excluded from the pale of the American Association for the Advancement of Science, I would here simply mention that in regard to the fungine elements apparent; *e. g.*, in diphtheria, it must never be forgotten that the formed mycelia may be long preceded in time by whatever morbid molecular germs may be circulating in the lymphatic system, etc. The appearance of the commonest corruptive agent, in places so favorable, as is a purulent exudation, steeped in saliva which cannot be swallowed, and remains permanently exposed to air, is but a natural consequence, and by no means argues a "probably local origin" of this disorder; which, together with the "black-tongue," † suffi-

* Carpenter, Microscope, § 386.

† The black-tongue, or "cold plague," results when a tumor is formed in the

ciently resembles the "oriental plague," such as it has occurred in Russia. The glandular swelling, however (instead of being located chiefly in the groins), in diphtheria is located round the throat, as in the glanders of horses. It is also generally characterized by a prickly, often purulent-tipped, scarlet rash (the dreaded "Scharlach-Friesel" and "*angina gangrænosa*" of yore), and often exhibits vibices of a hand's size, all over the body.

The locality of the tumor, evidently, is its most formidable complication; since it emphatically "incarcerates" both the grand sympathetic and pneumogastric nerves; while it also effectually strangulates both the *vena jugularis* and the throat.

This terrible swelling, however, like other pyæmic and specific (cadaverous and syphilitic) tumors, is most readily and effectually dispelled by the external application of blue mercurial ointment, when aided by a strong emetic dose of ipecac, and by calomel and quinine; in consideration of the state of the spleen and liver, respectively, — this treatment giving a mortality of about three per cent only. As for the fungous vegetation in the fauces, it is then easily kept down with a syrup of citrate of iron, (ant-) "ozonized" with oil of cloves. The caustic, however, in the majority of cases, also serves to increase the strangulation of all the vital conductors, as above specified; hence the comparative mortality, even when the fungous vegetation *in loco* had been entirely suppressed by its use. I would therefore warn the zealous theorizing practitioner, who, without a knowledge of fungi, attempts to destroy what he considers a fungous parasite (and for aught such it may be), to beware lest, in such premature and suicidal attempts, the specific agents of our own vitality * be not impaired, first of all. Let it therefore always be remembered, not to hurt our own constitutive "fermentic," "zymotic," or creatorial germ-molecules; † for of such little ones is the kingdom of life itself.

mesial line, strangulating (garotting) the circulation of the tongue. The latter rapidly swells to the size of a small apple, gagging the entire oral cavity. It is black as ink, and "marbled" as a map. A liquid emetic, artificially administered, produces an instant relief, if yet effectual on the comatose patient, whose pulse is low. It is but one of the forms of diphtheria.

* This refers most particularly to "disinfectants" that are destructive to primitive life generally, such as the asphyxiating carbolic acid, effectual in the cesspool, but injurious to breathe.

† The Latin words *germen* and *fermentum* are etymological twins, — the Greek and Spanish also frequently substituting an "h," etc., for the Latin "f," as in the case of ἀρμὸς, hermetic and *firmus*; *ferrum* and *hierro*, etc. In a German dialect the word "germ" is idiomatically used for yeast.

IV. ETHNOLOGY.

1. On Some Peculiarities of the Eskimo Dialect. By William H. Dall, of Washington, D. C.

Having devoted some attention for a number of years to matters connected with North American Ethnology and Philology, I improved the opportunity afforded during the winter of 1869–70, by the presence in Washington of two native Eskimo, and obtained a very large number of grammatical forms of the Repulse-Bay dialect.

These Eskimo, man and wife, are well known throughout the country as the people who accompanied Captain Hall, during his lectures in this country, and his explorations in the north. Both of them spoke enough English to comprehend readily what I required; and a slight knowledge of the dialect of the Western Eskimo — acquired during several years' residence and travel near Norton Sound, Bering Sea — assisted me in communicating with them.

My conversations with them extended over several months, at short intervals; and the same forms were repeatedly gone over, both by asking for the Eskimo rendering of English forms, carefully explained, and by asking for an English equivalent for the Eskimo phrases which I had taken down during a previous sitting. In this way I endeavored to eliminate errors as far as possible, and while I cannot hope to have succeeded in doing so entirely, yet it is probable that, of the several thousand phrases and grammatical forms recorded, the majority are mainly correct.

While the reduction to a grammatical system of the entire mass of observations, will be a work of much more labor and time than I have yet had opportunity of bestowing upon it; still, some peculiarities of the language are so evident to the most superficial student that they seem worthy of immediate publication. I have been the more impressed with them from the fact that they agree essentially with the descriptions of Crantz and Egede, and with my own observations upon the north-west coast of America, while they do not seem to entirely accord with the views expressed in a later work by Kleinschmidt upon the grammar of the Greenland

dialects.* The latter adds to its very complex, and by no means clear or satisfactory grammatical system, the further complication of being written in a very peculiar and awkward German dialect; so that it is often exceedingly difficult to comprehend his meaning, which is but slenderly elucidated by examples, which are seldom rendered into German even when given. Hence the differences which I have noticed may be due to a want of comprehension of his meaning, rather than to any great differences in the several dialects. That there are differences of some weight between the grammatical forms of closely adjacent Eskimo tribes is, however, evident from the remarks of the male Eskimo, previously referred to, when speaking of the dialect of King William's Land, and comparing it with that of his own people at Repulse Bay.

The discussion of these differences, and the endeavor to elucidate the various special modifications of the substantives and other parts of speech, will form the subject of a future paper. At present I wish to call attention to the wonderful variety of the forms of the verbs, especially the transitive verbs, which exceed those of any other known language.

The transitive verbs in the dialect in question appear to have an indicative, subjunctive, potential, and imperative mood. Each of these has an interrogative, affirmative, and negative form. The imperative has two subordinate forms which may be termed absolute and optative. The former orders or demands; the latter begs or entreats. There seems to be no true infinitive.

The indicative has five tenses: the present, past imperfect, past perfect, future, and future perfect, of which the equivalents are, — *doing*, *just done*, *long since done*, *will do directly*, *will do by and by;* and in some cases there appears to be still another form of the past, including the idea of completion, and rendered by *just finished doing*.

It is well known that the Eskimo carry the dual form of the substantive through the complete declension. The verbs, with their suffixes, have changes of the termination or in the body of the suffix, not only to express and to agree with the person, case, and number of the subject, but also, in transitive verbs, a similar series of changes takes place in that part of the permanent suffix which indicates the object when a personal pronoun.

The result of this wonderful complexity of suffixes is to multi-

* Grammatik der grönländischen Sprache, mit theilweisem Einschluss des Labradordialects. Von S. Kleinschmidt. Berlin, 1851. 8vo., pp. 182.

ply the forms of the verb to an extraordinary extent; and yet it would seem as if all the Eskimo spoke grammatically, though the effort of the mind necessary to retain these various forms would be stupendous to a European. I call to mind an instance in which a young Innuit spoke ungrammatically to one of his comrades, while travelling with me, in a matter which offered no room for a *double entendre*, yet he was the subject of *badinage* among them for a week afterwards; they also never wearied of ridiculing the bad grammar of the Indians and Russians who attempted to speak the Innuit tongue outside of the usual trading jargon.

The total number of inflections in the affirmative indicative mood amounts to three hundred and ninety. In the indicative, subjunctive, and potential, through the affirmative, negative, and interrogative forms, with the addition of the imperative, there is a total of over three thousand one hundred inflections, all different and invariable.

As an example of them, the following specimen of the conjugation of the affirmative form of the indicative mood of the transitive verb *ermityŭk*, is given. It will be noticed that the inflections are classified with reference to the relations of the subject and object, which has appeared the most satisfactory method of presenting the structure of the verb. Any table which showed the exact relation of each inflection to the others allied to it, would necessarily be very complicated, and much less clear than the linear system here adopted, though it must be confessed that the latter is not without its disadvantages. As before stated, perfect accuracy is not claimed for it, indeed, under the circumstances, it would be hardly reasonable to expect it; yet it may be hoped that the errors are not very numerous. It has been subjected to four several revisions since it was first written out, and it may be said in its favor that the Eskimo found but few errors needing correction.

The sounds are as follows:—

VOWELS.

a, as in father.	e, as in her.	ee, as in sheen.
i, as in pit.	o, ow, as in cow.	ū, as in Luke.
ŭ, as in hut.	y, as in cry.	ny, as in cañon.

CONSONANTS (USUALLY AS IN ENGLISH).

ch, as in church. ng', rolling nasal.

n, terminating a word after a vowel ŭ, soft nasal.

y, between two vowels, as a consonant; as in young.

The accent indicates the stress only. It will be observed that in a large number of cases this falls on the fourth syllable.

PARTICIPLES.

Washing; Ermik′ tŭ, — tŭk, — tŭn. Washed; Ermigŭrŭk′-tŭ, — tŭng, tŭn.

INDICATIVE MOOD.

PRESENT TENSE.

Object in the first person singular.

SINGULAR.

I wash myself.	Ermiklŭ′nga.
Thou washest me.	Ermi′ng'ŭh.
He, she, or it washes me.	Ermikpāā′nga.

DUAL.

You two wash me.	Ermiglŭshinga′.
They two wash me.	Er′ming-mŭ′nga-ik′wŭng.

PLURAL.

Ye wash me.	Ermingnyŭ′k pŭssing′y.
They wash me	Ermithlŭ′lŭng-mŭ′nga.

Object in the second person singular.

SINGULAR.

I wash thee.	Ermigit′.
Thou washest thyself.	Ermikpee′n.
He washes thee.	Ermikleetiny′.

DUAL.

We two wash thee.	Ermingnyŭk-po′wŭh
They two wash thee.	Ermikpŭ′ting-ik′wŭng.

PLURAL.

We wash thee.	Erming'nyŭk′pŭgŭnŭni′.
They wash thee.	Ermikpŭ′tih.

Object in the third person singular.

SINGULAR.

I wash him, her, or it.	Ermiglŭ′gŭ.
Thou washest him, her, or it.	Ermikpee′-ŭ.
He washes him.	Ermiktŭngina′h.
He washes himself.	Ermiktŭin′ah.

DUAL.

We two wash him, her, or it.	Erming′nyŭkpŭgŭwy.
You two wash him, her, or it.	Ermigyŭkpŭ′shing.

They two wash him, her, or it.	Ermiktüngü ' ng ' ing ' na.
We two wash each other.	Ermignyag ' ayük.
You two wash each other.	Ermighütow ' chüng.
They two wash each other.	Ermükatow ' chüng.

PLURAL.

We wash him, her, or it.	Ermikahtiün ' a.
Ye wash him, her, or it.	Ermikpissing-ü ' na.
They wash him, her, or it.	Ermiktüngani ' na.
We wash each other.	
Ye wash each other.	Ermükatow ' chü.
They wash each other.	Ermükatow ' chün.

Object in the first person dual.

SINGULAR.

Thou washest us two.	Ermiktee ' -üng.
He, she, or it washes us two.	Ermiglitiyüngi'.

DUAL.

We two wash ourselves.	Erming ' nyapüg ' lee-y.
You two wash us.	Ermiglitiyü'.
They two wash us two.	Ermükatow ' tiükwa.

PLURAL.

Ye wash us two.	Ermikpā ' tiyü.
They wash us two.	Ermikpa ' tiyüng.

Object in the second person dual.

SINGULAR.

I wash you two.	Ermigi ' ting.
He washes you two.	Ermikleeshingy'.

DUAL.

We both wash you two.	Ermükatow ' titā.
You both wash yourselves.	Ermiglü ' tiglü.
They both wash you two.	Erming 'yükpugālee-y'.

PLURAL.

We wash you two.	Erming ' nyükpü ' gü-ük ' wün.
They wash you two.	Ermikpü ' ssing-ük ' wüng.

Object in the third person dual.

SINGULAR.

I wash those two.	Ermiktü ' ka.
Thou washest those two.	Ermikshee ' kü.
He washes those two.	Ermiktünginik ' wüng.

DUAL.

We two wash those two.	Ermingnyük pü ' gli-ikwa.
You two wash those two.	Ermingnyük pü ' ting.
They two wash those two.	Atünin-ükwa-ermükatow ' chü.

PLURAL.

We wash those two.	Ermŭkatow′ yŭmikwŭng.
Ye wash those two.	Ermikpissee′ ng-ŭkwŭng.
They wash those two.	Ermik′ tŭng-ikwŭng.

Object in the first person plural.

SINGULAR.

Thou washest us.	Ermiktee′ -ŭ.
He washes us.	Ermik pŭ′ tiyŭ.

DUAL.

You two wash us.	Ermiglŭtiyŭn′.
They two wash us.	Ermithlŭh-mŭtiyŭ-ikwa.

PLURAL.

We wash ourselves.	Ermigŭ′ tta.
Ye wash us.	Ermŭkatowtity′.
They wash us.	Erminyŭkpŭ′ tiyŭ.

Object in the second person plural.

SINGULAR.

I wash you.	Ermigich′i.
He washes you.	Ermikpishiyŭ.

DUAL.

We two wash you.	Ermikthlŭng′ nyapow′ ŭ-ŭkwa.
They two wash you.	Ermikpŭ′ shee-ŭkwa.

PLURAL.

We wash you.	Ermŭkatow′ ti-thlŭlŭkty′.
Ye wash yourselves.	Ermithlŭkpis′ see.
They wash you.	Ermik′ tŭm-ikwa.

Object in the third person plural.

SINGULAR.

I wash them.	Ermigi-ŭk′ tŭn.
Thou washest them.	Ermik-shee′ -ŭ.
He washes them.	Ermik′ -tŭngin-ik′ wa.

DUAL.

We two wash them.	Erming′ nya-wŭ′ wŭt.
You two wash them.	Ermingnyŭkpŭ′ shingy.
They two wash them.	Ermiktahping-ik′ wa.
They two wash themselves.	Ermŭkatowchŭ.

PLURAL.

We wash them.	Ermingyŭk′ pŭn-ikwa.
Ye wash them.	Ermik pis′ seeng-ikwa.
They wash them.	Ermik′ tŭng-ikwa.
They wash themselves.	Ermiktŭ′ apin-ikwa.

PAST IMPERFECT TENSE.

Object in the first person singular.

SINGULAR.

I washed myself (lately).	Ermiglŭ ' ngā.
Thou washedst me.	Ermikawi ' ngā.
He, she, or it washed me.	Ermikawŭ ' ngā.

DUAL.

You two washed me.	Ermilowŭtchi ' ngā.
Those two washed me.	Ermŭkowmŭ ' ngā.

PLURAL.

Ye washed me.	Ermŭkowŭt ' chingā.
They washed me.	Ermŭkowŭ ' ngā.

Object in the second person singular.

SINGULAR.

I washed thee.	Ermiglŭgit'.
Thou washedst thyself.	Ermŭkowee'.
He washed thee.	Ermŭkowŭ ' ti.

DUAL.

We two washed thee.	Ermŭko-yŭ ' kpŭng.
Those two washed thee.	Ermŭkowŭt ' i.

PLURAL.

We washed thee.	Ermŭkowŭ ' tiyŭn.
They washed thee.	Ikwa-ermikpŭt ' i.

Object in the third person singular.

SINGULAR.

I washed him, her, or it.	Ermŭkowŭ ' gā.
Thou washedst him, her, or it.	Ermikowyānŭ ' nā.
He washed him (another).	Ermŭkow ' yŭ-ŭ ' nā.
He washed himself.	Ermŭkowow ' nā.

DUAL.

We two washed him, her, or it.	Ermŭkowyŭk ' pŭn.
We two washed each other.	Ermŭkatow ' tŭkowinŭ.
You two washed him, her, or it.	Ermŭkowigikŭ.
You two washed each other.	Ermŭkatowtŭkowis ' sing.
They two washed him, her, or it.	Ermŭkowŭ ' nā.
They two washed each other.	Ermikowŭt ' ing.

PLURAL.

We washed him, her, or it.	Ermikowŭt ' iŭna.
Ye washed him, her, or it.	Ermŭkowŭt ' chiŭn '.
They washed him, her, or it.	Ermŭkow ' yŭng ' ŭn.

Object in the first person dual.

SINGULAR.

Thou washedst us two.	Ermikowig′ eeyû.
He, she, or it washed us two.	Ermŭkowit′ y-û.

DUAL.

We both washed ourselves.	Ermŭkowûn′ a.
You two washed us two.	Ermŭkowiwig′ iyû.
They two washed us two.	Ermŭkowa′ tyûn-ûk′ wŭng.

PLURAL.

You washed us two.	Ermilowkpŭt′ iyû-ik′ wŭng.
They washed us two.	Ermŭkowit′ iyû-ûk′ wŭng.

Object in the second person dual.

SINGULAR.

I washed you two.	Ermiglŭ′ gilû.
He washed you two.	Ermikowig′ in-ûk′ wŭng.

DUAL.

We two washed you two.	Ermiyŭklŭk′ pûn-ûkwŭng.
You two washed yourselves.	Ermilowiviting.
They two washed you two.	Ermŭkowŭsseeng′ -ûkwŭng.

PLURAL.

We washed you two.	Ermŭkowût′ iyûn-ûk′wŭng.
They washed you two.	Ermŭkowŭs′ see-ûk′ wŭng.

Object in the third person dual.

SINGULAR.

I washed those two.	Ermŭkowya′ ka.
You washed those two.	Ermŭkalŭk′-pigee.
He washed those two.	Ermikpŭg′ ing-ik′ wŭng.

DUAL.

We two washed those two.	Ermŭkowyŭk′ pûn-ûk′ wŭng.
You two washed those two.	Ermŭkowis′ sing-ûk′ wŭng.
They two washed those two.	Ermŭkatow′ tŭkow′ yung-uk′ wŭng.

PLURAL.

We washed those two.	Ermŭkyŭk′ tabûn-ûk′ wŭng.
Ye washed those two.	Ermikkowis′ si-ûng-ûk′ wŭng.
They washed those two.	Ermukow′ yŭng-ik′ wŭng.

Object in the first person plural.

SINGULAR.

Thou washedst us.	Ermika′ lŭkpit′ eeyûng.
He washed us.	Ermŭkowŭt′ iýûn.

DUAL.

You two washed us.	Ermilowkpit′ eeyûn′.
They two washed us.	Ermŭkowat′ iyûn-ûk′ wa.

PLURAL.

We washed ourselves.	Ermŭkowŭt′ ā.
You washed us.	Ermilowk pŭt′ iyŭ-ik′ wŭng.
They washed us.	Ermŭkowŭt′ iyŭ-ŭk′ wŭng.

Object in the second person plural.

SINGULAR.

I washed you.	Ermiglich′ i.
He washed you.	Ermikowig′ in-ŭk′ wa.

DUAL.

We two washed you.	Ermiyuktŭk′ pŭn-ŭk′ wa.
They two washed you.	Ermŭkowis′ see-ing-ŭk′ wa.

PLURAL.

We washed you.	Ermŭkowŭt′ iyŭn-ŭk′ wa.
Ye washed yourselves.	Ermŭkowi′ gi.
They washed you.	Ermŭkowŭs′ see-ŭk′ wa.

Object in the third person plural.

SINGULAR.

I washed them.	Ermilowk′ tākā.
Thou washedst them.	Ermilowk pig′ ee.
He washed them.	Ermŭkowŭk.

DUAL.

We two washed them.	Ermŭkowyŭk′ pŭn-ŭk′ wŭng.
You two washed them.	Ermŭkowis′ sing-ŭkwŭng.
They two washed them.	Ermŭkatow′ tŭkow′ yŭng-ŭk′ wā.
They two washed themselves.	Ermŭkow′ yŭng-ŭk′ wŭng.

PLURAL.

We washed them.	Ermŭkowyŭk′ tabŭn-ŭk′ wŭng.
Ye washed them.	Ermŭkowis′ seeyŭng-ŭk′ wŭng.
They washed them.	Ermŭkowŭt′ iyŭng-ŭk′ wŭng.
They washed themselves.	Erm-ik′ pŭn-ik′ wa.

PAST PERFECT TENSE.

Object in the first person singular.

SINGULAR.

I washed myself (long ago).	Ermikalapŭng′ a.
Thou washedst me.	Ermigwŭh′ winga.
He, she, or it washed me.	Ermilow′ yŭwŭ′ nga.

DUAL.

You two washed me.	Ermilow′ yŭwŭtching′ a.
They two washed me.	Ermiyŭmŭng′ a-ik′ wŭng.

PLURAL.

Ye washed me.	Ermiyŭwŭt′ chinga.
They washed me.	Ermiyŭmŭng′ a-ik′ wa.

Object in the second person singular.

SINGULAR.

I washed thee.	Ermikălăpă′ gă.
Thou washedst thyself.	Ermilowkpee.′
He washed thee.	Ermiyŭwŭt′ ee.

DUAL.

We two washed thee.	Ermiyŭyŭk′ pŭng-ŭk′ wŭng.
Those two washed thee.	Ermiyŭwŭt′ i-ŭk′ wŭng.

PLURAL.

We washed thee.	Ermiyŭwŭt′ iyŭn′.
They washed thee.	Ermilowkpŭt′ ee.

Object in the third person singular.

SINGULAR.

I washed him, her, or it.	Ermiyŭyŭk′ a.
Thou washedst him, her, or it.	Ermiyŭya′ ga.
He washed him (another).	Ermiyŭyŭnga.
He washed himself.	Ermiyŭyŭhwŭ′.

DUAL.

We two washed him, her, or it.	Ermilowk′ tŭkpŭng.
We two washed each other.	Ermiyŭ′-ŭnŭ.
They two washed him, her, or it.	Ermilowktŭng′ a-ŭna.
You two washed him, her, or it.	Ermilowyŭwizh′ ikŭ.
You two washed each other.	Ermŭkatow′ tiyŭwis′ sing.
They two washed each other.	Ermiyŭwŭt′ ing.

PLURAL.

We washed him, her, or it.	Ermilowk′ towŭng.
We washed each other.	Ermŭkatow′ tiyŭ-ŭn′ a.
Ye washed him, her, or it.	Ermilowŭtchiŭn.
Ye washed each other.	
They washed him, her, or it.	Ermiyŭyŭng′ ŭn.
They washed each other.	

Object in the first person dual.

SINGULAR.

Thou washedst us two.	Ermiyŭ-it′ ee-ŭ.
He, she, or it washed us two.	Ermilow′ yŭ-it′ eeyŭ.

DUAL.

We two washed ourselves.	Ermiyŭwŭn′ a.
You two washed us two.	Ermilow′ yuwi-wit′ iyŭ.
They two washed us two.	Ermilowyŭat′ iyŭ-ŭkwŭng.

PLURAL.

Ye washed us two.	Ermilow' yŭwŭt' iyŭ.
They washed us two.	Ermilow' yŭwŭt' iyŭ-ŭk' wŭng.

Object in the second person dual.

SINGULAR.

I washed you two.	Ermikalata' ka.
He washed you two.	Ermiyŭ' wigin-ŭk' wŭng.

DUAL.

We two washed you two.	Ermilowktŭk' pŭn-ŭk' wŭng.
You two washed yourselves.	Ermilow' yŭwis' sing.
They two washed you two.	Ermilow' yŭ-ŭs' see.

PLURAL.

We washed you two.	Ermiyŭwŭt' iyŭn-ŭk' wŭng.
They washed you two.	Ermilow' yŭ-ŭs' see-ŭk' wŭng.

Object in the third person dual.

SINGULAR.

I washed those two.	Ermigiya' ka.
Thou washedst those two.	Ermitay ŭpee' yee.
He washed those two.	Ermiyŭwŭg' in-ik' wŭng.

DUAL.

We two washed those two.	Ermilowk' tŭkpŭn-ŭk' wŭng.
You two washed those two.	Ermilowyŭwig' in-ŭk' wŭng.
They two washed those two.	Ermŭkatow' tiyŭ' nŭk-ŭk' wŭng.
They two washed themselves.	Ermiyŭ' yŭng-ŭk' wŭng.

PLURAL.

We washed those two.	Ermilowk' tabŭn-uk' wŭng.
Ye washed those two.	Ermilowis' siyŭng-ŭk' wŭng.
They washed those two.	Ermilowk' tŭng-ik' wŭng.

Object in the first person plural.

SINGULAR.

Thou washedst us.	Ermitayŭmit' iyŭn'.
He washed us.	Ermiyŭwut' iyŭn'.

DUAL.

You two washed us.	Ermiyŭ' wŭt pit' iyŭn'.
They two washed us.	Ermilow' yŭatiŭn-ik' wŭng.

PLURAL.

We washed ourselves.	Ermilowŭt' a.
Ye washed us.	Ermiyuwis' see.
They washed us.	Ermiyŭyŭk' a.

Object in the second person plural.

SINGULAR.

I washed you.	Ermikŭllatŭk ' a.
He washed you.	Ermiyŭ ' wigin-ŭk ' wa.

DUAL.

We two washed you.	Ermiyŭ' yŭhwŭt.
They two washed you.	Ermiyŭyŭhwook.

PLURAL.

We washed you.	Ermilowyŭwŭt ' iyŭn-ŭk ' wa.
Ye washed yourselves.	Ermiyŭ-iss ' ing.
They washed you.	Ermiyŭwŭt-i ' ik ' wa.

Object in the third person plural.

SINGULAR.

I washed them.	Ermigiyŭk ' a.
Thou washedst them.	Ermiyŭwig ' ee.
He washed them.	Ermiyŭwŭg ' in-ik ' wa.

DUAL.

We two washed them.	Ermilowyŭyŭkpŭn.
You two washed them.	Ermilowyŭwissigin-ŭkwa.
They two washed them.	Ermŭkatowtiyŭn-ŭkwa.
They two washed themselves.	Ermilowyŭ-ŭs ' see-ik ' wa.

PLURAL.

We washed them.	Ermilowk ' tabŭnŭk ' wa.
Ye washed them.	Ermilowis ' seeyŭng-ŭk ' wa.
They washed them.	Ermilowk ' tung-ik ' wa.
They washed themselves.	Ermiyŭ '-ŭn-ik ' wa.

FUTURE TENSE.

Object in the first person singular.

SINGULAR.

I will wash myself (directly).	Ermŭkow ' imŭlli.
Thou wilt wash me.	Erming ' nya ' lŭk-pŭng ' ŭlli.
He will wash me.	Erming ' nya ' lŭkpă ' gă.

DUAL.

You both will wash me.	Ermingnyas ' nŭk-pŭtsinga'.
They both will wash me.	Ermig ' iyŭ-nya ' lŭ-rŭttinga'.

PLURAL.

Ye will wash me.	Ermignya ' lŭk-pŭtchingi'.
They will wash me.	Ermingnya ' lŭk-pŭng ' a.

Object in the second person singular.

SINGULAR.

I will wash thee.	Ermŭkowi′ wee.
Thou wilt wash thyself.	Ermingnya′ lŭk-pŭti.
He will wash thee.	Ermingnya′ lŭk-pŭtil′ li.

DUAL.

We two will wash thee.	Ermingnyalŭriwŭt′ ing.
They two will wash thee.	Ermigiyu′ nyalŭ-rŭtchinga′.

PLURAL.

We will wash thee.	Ermingnya′ lŭk-pŭtigil′ li.
They will wash thee.	Ermingnya′ lŭk-pŭg′ in.

Object in the third person singular.

SINGULAR.

I will wash him, her, or it.	Ermingnya′-tŭee′ nŭk-pŭng′ a.
Thou wilt wash him, her, or it.	Ermila′ lŭk-pŭl′ li.
He will wash him, her, or it.	Ermingnya′ lŭk-pagŭl′ li.
He will wash himself.	Ermingnya′ lŭk-pŭn′.

DUAL.

We two will wash him, her, or it.	Ermingnya′ lŭk-towŭng′ na.
We two will wash each other.	Ermŭkatow′ ti-nya′ lŭk-pŭn′ i.
You two will wash him, her, or it.	Ermingnya′ snŭkpŭssig′ li.
You two will wash each other.	Ermŭkatow′ ti-nya′ lŭkpŭs′ si.
They two will wash him, her, or it.	Ermi′ giyŭ-nya′ lŭ-row′ igin.
They two will wash each other.	Ermŭkatow′ ti-nyalŭk′ tŭng.

PLURAL.

We will wash him, her, or it.	Ermignya′lŭkpŭwŭl′ li.
Ye will wash him, her, or it.	Ermingnya′ lŭktŭk′ i.
They will wash him, her, or it.	Ermigiyŭnya′ lŭkŭnŭ.
We will wash each other.	Ermŭkatow′ tiknya′ lŭkpŭs′ see.
Ye will wash each other.	Ermŭkatow′ tŭnya′ lŭktŭn.
They will wash each other.	Ermŭkatow′ tinya′ lŭktŭn.

Object in the first person dual.

SINGULAR.

Thou wilt wash us two.	Ermila′ lŭkpŭg′ li.
He, she, or it will wash us two.	Ermingnya′ lŭkpŭg′ li.

DUAL.

We two will wash ourselves.	Ermingnya′ lŭpŭgtow.
You two will wash us two.	Ermingnya′ riwŭ′ wŭ.
They two will wash us two.	Ermigiyŭ′ nya′ lŭmig′ ŭnŭ.

PLURAL.

Ye will wash us two.	Ermingnya′ lŭktŭhwŭm′ my.
They will wash us two.	Ermigiyŭ′ nya′ lŭkmŭng′ a.

Object in the second person dual.

SINGULAR.

I will wash you two.	Ermŭkowmigŭt' ching.
He will wash you two.	Ermingnyā' lŭk pŭs' sing.

DUAL.

We two will wash you two.	Ermingnya' lūriwissee' ng'.
You two will wash yourselves.	Ermingnyăk pūs' sing.
They two will wash you two.	Ermigiyū' nyalūrŭtiktow'.

PLURAL.

We will wash you two.	Ermingnyā' lŭkpŭtigig' li.
They will wash you two.	Ermingnya' lŭk pūs'sigli.

Object in the third person dual.

SINGULAR.

I will wash those two.	Ermigiyŭkowissee' ng'.
Thou wilt wash those two.	Ermingnyā' migŭtchee' ng'.
Ye will wash those two.	Ermingnyā' lŭk pū' wū.

DUAL.

We two will wash those two.	Ermingnya' lŭktow' ŭng-ŭk' wŭng.
You two will wash those two.	Ermingnyā' lŭkpŭt' ing-ŭk' wŭng.
They two will wash those two.	Ermigi-ū' miŭtiktow.'

PLURAL.

We will wash those two.	Ermignya' lŭkowŭl' li.
Ye will wash those two.	Ermingnya' lŭktŭk' ŭtow.
They will wash those two.	Ermigiyūnya' lŭk-mŭt' ting.

Object in the first person plural.

SINGULAR.

Thou wilt wash us.	Ermilā' lŭk-pŭttil' li.
He will wash us.	Ermingnya' lŭk-pūssil' li.

DUAL.

You two will wash us.	Ermingnya' lŭk pŭtsil' li.
They two will wash us.	Ermigiyūnya' lūmiŭtiking'.

PLURAL.

We will wash ourselves.	Ermingnya' lŭkpūwŭd' li.
Ye will wash us.	Ermingnya' lŭkpŭtsee'.
They will wash us.	Ermigyūnya' lŭk mŭt' ta.

Object in the second person plural.

SINGULAR.

I will wash you.	Ermŭkowmigŭt' chee.
He will wash you.	Ermingnya' lŭkpŭssillich' i.

DUAL.

We two will wash you.	Ermingnya' lūriwis' see.
They two will wash you.	Ermigiyū-nya' lūrŭt' ikŭ.

PLURAL.

We will wash you.	Ermignya' lūriwū' wūt.
Ye will wash yourselves.	Ermignya' lŭkpūtingi.
They will wash you.	Ermingnyaluk-paa' nga.

Object in the third person plural.

SINGULAR.

I will wash them.	Ermingnya' lŭkpūng' a.
Thou wilt wash them.	Ermingnya' lŭk pig' in.
He will wash them.	Ermingnya' lŭk pūkūl' li.

DUAL.

We two will wash them.	Ermingnya' lŭktow' ūng-ūk' wa.
You two will wash them.	Ermingnyalŭkpūs' si.
They two will wash them.	Ermignya' larūtiktow'.
They two will wash themselves.	Ermigiyū' nyalūrūm' ming.

PLURAL.

We will wash them.	Ermignya' lŭkriwis' see.
Ye will wash them.	Ermingnya' lŭktŭk' a.
They will wash them.	Ermingiyūnya' lŭkrūt' ta.
They will wash themselves.	Ermingnyăk' tūn.

FUTURE PERFECT TENSE.

Object in the first person singular.

SINGULAR.

I will wash myself (sometime).	Ermiyūma' hā-mŭl' li.
Thou wilt wash me.	Ermiyūla' lŭk-pūngŭl' li.
He will wash me.	Ermiyūma' lŭk-pā' gā.

DUAL.

You two will wash me.	Ermiyūmak' snŭk-pūtsing 'a.
They two will wash me.	Ermigila' lū-rŭt' tinga.

PLURAL.

Ye will wash me.	Ermiyūma' lŭk-pūtch' inga.
They will wash me.	Ermiyūma' lŭk-pūng 'a.

Object in the second person singular.

SINGULAR.

I will wash thee.	Ermila '-i-wee.
Thou wilt wash thyself.	Ermila' lŭk-pūt' i.
He will wash thee.	Ermiyūma' lŭk-pūtil' li.

DUAL.

We two will wash thee.	Ermiyūma' lūriwūs' sing.
They two will wash thee.	Ermigilā' lū-rŭt' ching.

PLURAL.

We will wash you.	Ermiyūma' lŭk-pūtigil' li.
They will wash you.	Ermiyūma' lŭk-pŭg' in.

Object in the third person singular.

SINGULAR.

I will wash him, her, or it.	Ermiyŭma' snŭk-pŭn' ga.
Thou wilt wash him, her, or it.	Ermiyŭma' lŭk-pŭl' li.
He will wash himself.	Ermiyŭma' lŭk-pŭn.'
He will wash him (another).	Ermiyŭma' lŭk-pagŭl' li.

DUAL.

We two will wash him, her, or it.	Ermiyŭma' lŭktowŭng' na.
We two will wash each other.	Ermŭkatow' tila' lŭkpŭn' i.
You two will wash him, her, or it.	Ermiyŭma' lŭkpŭssig' li.
You two will wash each other.	Ermŭkatow' tilalŭkpŭs' si.
They two will wash him, her, or it.	Ermigilā' lŭrowig' in.
They two will wash each other.	Ermŭkātow' tilŭktŭng'.

PLURAL.

We will wash him, her, or it.	Ermiyŭmā' lŭkowŭg' li.
We will wash each other.	Ermŭkātow' tikyŭmālŭk pŭs' see.
Ye will wash him, her, or it.	Ermiyŭma' lŭktŭs' sing.
Ye will wash each other.	Ermŭkatow' tŭyŭma' lŭktŭn'.
They will wash him, her, or it.	Ermilā' lŭkowŭ.'
They will wash each other.	Ermŭkātow' tila' lŭktŭn'.

Object in the first person dual.

SINGULAR.

Thou wilt wash us two.	Ermigiyŭla' lŭkpŭg' li.
He, she, or it, will wash us two.	Ermiyŭma' lŭkpŭg' li.

DUAL.

We two will wash ourselves.	Ermila' lŭk pŭg' tow.
You two will wash us two.	Ermingyŭma' ri-wŭ' wŭ.
They two will wash us two.	Ermigila' lŭwig' ŭnŭ.

PLURAL.

Ye will wash us two.	Ermiyŭma' lŭk-tŭhwŭm' mi.
They will wash us two.	Ermila' lŭkmŭng' a.

Object in the second person dual.

SINGULAR.

I will wash you two.	Ermiyŭmā' imeeŭt' ching.
He will wash you two.	Ermiyŭma' lŭk pŭs' sing.

DUAL.

We two will wash you two.	Ermiyŭma' lŭriwis' seeng'.
You two will wash yourselves.	Ermiyŭma' lŭkpŭs' seeng'.
They two will wash you two.	Ermigilā' lŭrŭtiktow.'

PLURAL.

We will wash you two.	Ermiyŭma' lŭk-pŭtigig' li.
They will wash you two.	Ermiyŭma' lŭk-pŭs' sigli.

Object in the third person dual.

SINGULAR.

I will wash those two.	Ermiyûma' reewis' seeng'.
Thou wilt wash those two.	Ermiyûmalo' rawis' seeng'.
He will wash those two.	Ermiyûma' lŭk pû' wû.

DUAL.

We two will wash those two.	Ermiyûma' lŭktowŭng-ûk' wŭng.
You two will wash those two.	Ermigyûma' lŭk pŭs' sing.
They two will wash those two.	Ermigirûngia' lŭktik' tow.

PLURAL.

We will wash those two.	Ermiyûma' lŭkowûl' li.
Ye will wash those two.	Ermiyûma' lŭktŭk' ûtow.
They will wash those two.	Ermigila' lû-mŭt' ting.

Object in the first person plural.

SINGULAR.

Thou wilt wash us.	Ermiyûla' lŭkpŭssil' li.
He will wash us.	Ermiyûma' lŭkpûssil' li.

DUAL.

You two will wash us.	Ermigyûma' lŭkpŭtsil' li.
They two will wash us.	Ermigla' lûmi-ŭt' iking.

PLURAL.

We will wash ourselves.	Ermiyûma' lŭk-pûwûd' li.
Ye will wash us.	Ermiyûma' luk-pŭtsee'.
They will wash us.	Ermigila' lû-mŭt' ta.

Object in the second person plural.

SINGULAR.

I will wash you.	Ermiyûma-imeeŭt' chee.
He will wash you.	Ermiyûma' lŭk-pûssillich' i.

DUAL.

We two will wash you.	Ermiyûma' lûriwis' see.
They two will wash you.	Ermigila' lûrŭtikŭ'.

PLURAL.

We will wash you.	Ermiyûma' lûriwû' wŭt.
Ye will wash yourselves.	Ermiyûma' lŭk-pŭt' ingy'.
They will wash you.	Ermiyûma' lŭk-paang' a.

Object in the third person plural.

SINGULAR.

I will wash them.	Ermila' lŭk pûng' a.
Thou wilt wash them.	Ermiyûla' lŭk pigeen'.
He will wash them.	Ermiyûma' lŭk-pûkŭl' li.

DUAL.

We two will wash them.	Ermiyŭma' lŭk-towŭng-ŭk'wa.
You two will wash them.	Ermigyŭma' lŭk-pŭs' si.
They two will wash them.	Ermigŭma' lărŭtiktow'.
They two will wash themselves.	Ermigila' lŭ-rŭm' ming.

PLURAL.

We will wash them.	Ermiyŭma' lŭriwis' see.
Ye will wash them.	Ermiyŭma' lŭktŭk' a.
They will wash them.	Ermiyŭma' lŭrŭt' ta.
They will wash themselves.	Ermiyŭma' lŭkak' tŭn.

The remaining forms, or the majority of them, including examples of, and in many cases the whole of each mood, tense, etc., in its several forms, are in course of preparation.

C. PRACTICAL SCIENCE.

I. MECHANICS.

1. On Proposed Improvements for Common Roads. By S. D. Tillman, of Jersey City, New Jersey.

If durability be the most essential quality in a good road, the ancient Romans excelled in the art of road-making. Of the twelve famous highways leading into their capital, vestiges of which are still to be seen, the Appian Way was the oldest. Originally its length was one hundred and forty-two miles; at a later period, it was extended to three hundred and eighty. It consisted of large blocks of smooth stone, accurately fitted together for the use of carriages, and a foot pavement on each side two feet wide. A part of the Tiburtine road, near Tivoli, still remains undisturbed, having been in use more than two thousand years. One of the most remarkable roads of which we have any account was that leading from Quito to Cuzco, built by the ancient Incas of Peru, nine hundred miles long, and seventy-five feet wide. According to Prescott, the historian, "it was conducted over pathless sierras covered with snow; galleries were cut for leagues through living rock; rivers were crossed by means of bridges

suspended in the air; precipices were scaled by stairways hewn out of the natural bed; and ravines of hideous depth were filled up with solid masonry."

However much we may admire the massiveness and permanency of ancient roads, when estimated by the modern standard of utility, such structures are found not to meet the requirements of this practical age. Modern engineering has demonstrated that speed, certainty, and safety are the three great requisites of inter-communication. An absolute and complete change in the means of travelling has been wrought by the introduction of the railway and the locomotive. One has given us a perfectly smooth and solid pathway of easy grade, its great economy being in its reduction to such narrow width as to sustain only two wheels, which are kept securely thereon by means of flanges; the other has provided a moving power ever ready and reliable, untiring in its energies and matchless in its speed. The change thus wrought in our own country, where the railway system is far more extensive than in any other, was more marked, because the ordinary roads had not been much improved, and were in a condition similar to those of England a hundred years before. The once famous turnpike extending from Albany to Buffalo, over one hundred feet in width, had been covered throughout its middle section, more than once, with broken stone, which, by the action of rain and frost, disappeared beneath the rich soil. Only forty years have elapsed since numerous stage coaches were running over this turnpike, making, during summer and winter, an average speed of eight or ten miles an hour, while in the spring and fall it did not equal that of the passenger boats on the Erie canal.

Previous to the introduction of the railway, numerous experiments were made for the purpose of improving the common highways, and more especially the pavements of cities and large towns. Of stone pavements, the cheapest and most objectionable is the cobble-stone; superior to this is the Belgian pavement, which consists of rough stone cubes, imbedded in sand. The most durable and costly, yet, in the end, cheapest stone pavement consists of stone blocks, about three inches thick and twelve inches square, set on end, with their broadest faces in contact and resting on a bed of concrete, like that now on Broadway, in the city of New York. Professor Mahan, in his essay on "Road-Making," states that asphaltic pavements — consisting of bitumen and sand — and wooden pavements have been extensively used in Europe, but

seem not to have answered the desired purpose. The most popular pavement in this country at present is made of wooden blocks, resting on a wooden foundation covered with bitumen, and separated from each other above by means of a thin partition of bitumen and gravel. The ease with which the horse travels on this pavement, and the almost entire absence of noise, are strong points in its favor. The question as to its durability on much-travelled thoroughfares has not yet been definitely settled. Roads made on the plans of Macadam and Telford are not used in the business streets of American cities, on account of the fine grit and dust resulting from the action of horseshoes and wheel-tires. It is needless to say, none of the plans alluded to fulfil all the conditions of a perfect pavement; since none of them embrace the admirable peculiarity of the railway, in providing for the wheel a perfectly smooth pathway. Obviously, the smooth, solid surface, on which great speed is attained by means of the locomotive, would on the common highway result in somewhat increased speed, with a great decrease in the power required to produce that speed; in other words, all loads could be transported more rapidly by employing not over one-third the number of horses now used to do the same work, and with far less wear and tear. To illustrate this point, let us take the most perfect pavement,—that already alluded to on Broadway,—where a pair of horses attached to an omnibus draw less than one-fourth the load drawn by a pair of horses attached to a street-railway car. Each of the wheels of an omnibus, in passing from one stone, falls slightly, and rises as much by sudden contact with another; thus a series of concussions are made by each wheel, which jerk the horses, jolt the passengers, and jar the vehicle. The number of noisy concussions thus made by an omnibus, in passing over one mile on the Broadway pavement, is about 63,000, and in one day's travel, of thirty miles, is 1,890,000.

It may be asserted with truth that the concussions are not so great on wooden pavements, as is proved by the absence of noise. This result is owing to the fact that wood is more elastic than stone, and gives slightly under pressure; yet, in this fact, lies the proof that a loaded wagon can be drawn with less effort over a good stone pavement than over one of wood; which will be apparent, if we reflect that the wheel, by its great pressure on the wood, is constantly sinking slightly below the general surface, and thus constantly forming an impediment before it which must be

overcome. When the wood is wet the sinking of the wheel is perceptibly increased. According to the experiments made by Sir John Macneill, to determine the force of traction for one ton on level roads, it was found that on a gravel road the force is one hundred and forty-seven pounds; on a broken stone surface, laid on an old flint road, sixty-five pounds; on a broken stone road, covering a rough stone pavement bottom, forty-six pounds; on a good stone pavement thirty-three pounds. To this it may be added, that the force on a railway is eight pounds; in other words, that one horse will draw on a railway more than four can on a good stone pavement. Nicholas Wood, in his treatise on railways, estimates the force of traction for one ton on a smooth turnpike road at seventy-three pounds, and on railways at eight and one-half pounds; that is to say, two horses will draw more on a railway than seventeen horses can on an English turnpike.

The important problem now presented, is to construct city pavements so as to embrace the essential features of the railway. Its successful solution depends on the following conditions: —

1st. To form a solid and virtually smooth surface of an unyielding material, on which the carriage wheels may roll.

2d. To provide a foothold for horses in passing over such surface.

If the material used for this purpose is stone, in small blocks, we find by experience that, when laid with the utmost care, there is always a space left between these blocks, over which the wheel must roll; and in passing from a stone the wheel strikes the next with a blow proportionate to the load it sustains, the effect of which is to wear off the edge of the stone; and the wheel passing in an opposite direction wears off the opposite edge, so that the space between the stones is gradually widened, thereby increasing the force of the blow by the wheel; and thus such stones, in time, become rounded on two sides, and in that form are hardly more efficient than cobble-stones.

If the material employed were iron, it might be cast in hollow blocks so as to be interlocked, and its face could be provided with a series of smooth, raised surfaces, alternating with depressions or indentations; and the raised surfaces could be so arranged that the wheel would be constantly sustained on a true grade by rolling over one raised surface, which should touch the middle of the tire, or rolling over two raised surfaces which, either simultaneously or alternately, would give a bearing to the wheel-tire near its sides.

The transverse depressions thus formed allow the toe-cork, or fore part of a horseshoe, to sink below the raised or grade surface, and by means of such surfaces the horse would find a sufficient bearing against which to exert the leverage of his foot.

Cast-iron blocks thus made might cover the whole surface of a street; but as the cost of such a pavement would be a serious obstacle to its general adoption and use, the more feasible plan is to provide an iron pathway or tramway for each wheel of the vehicle, and fill in the spaces between such iron pathways with either stone, wood, or asphaltic composition, thus providing a pathway for the horse. A pair of iron paths, each about one foot wide, and placed four feet and a third apart, would provide a tramway suitable for vehicles of various widths, embracing the pleasure carriage, cart, lumber-wagon and omnibus, and a pathway for a pair of horses between such tracks. The tramway could be made of hollow cast-iron blocks, each about a foot long, with a projection on one end and a recess on the other, so that when brought together and interlocked, the pressure on the edge of one block would be transferred to the centre of the next. Such blocks could be laid directly on pure sand, or be filled in from beneath with wood, and laid on a perfectly solid and smooth foundation. The tramway could also be constructed of longer wrought-iron or cast-iron plates, having longitudinal ribs or webs underneath to strengthen them; each resting securely, by means of spikes, on one-half of the top of a wooden post set in the ground, and reaching below the action of frost. This plan would give a permanent pathway for the wheel, independent of that for the horse; and also would be unaffected by any changes which the surrounding earth might undergo by the action of water or frost. The face of such tramway could be composed of alternating smooth elevations and depressions, of a series of narrow ribs running longitudinally, or of a smooth surface, having on it one or more lines of elevations and depressions, so arranged as to provide a foothold for horses, and, when placed on the edges of the tramway, to allow wheels to pass obliquely over it without sliding.

A single pair of iron wheel-paths of this description, placed in the middle of a street not much used, would accommodate all carriages which, in this case, would have to turn off from the track in passing each other. In a more busy street two pair of tramways would accommodate carriages going in opposite directions. In still more crowded streets four pair of tramways could be laid

down,—two for loaded teams moving slowly in opposite directions, and two for carriages moving more rapidly in opposite directions, and on great central thoroughfares, like Broadway in the city of New York, my plan is to lay down longitudinal iron paths, from six to nine inches in width, alternating with stone, wood, or asphaltic footway for a single horse about two feet in width, so as to fill up the whole width of the street with alternate wheel-ways and horse-ways. It need hardly be added that such tramways would make the use of the steam carriage practicable.

Such, briefly stated, are the main features of the iron tramway system, which, if introduced on common roads, would add to the comforts of the pleasure carriage, save the wear of vehicles, make every horse four times more efficient, and, in fine, work a revolution as radical and beneficial as that which followed the introduction of the railway.

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2. On Improvements in Inland Navigation. By Samuel D. Tillman, of Jersey City, N. J.

The canals and navigable rivers in the territory of the United States form a network of transit, unrivalled in extent and importance. In the State of New York alone, the artificial water channels of communication have a total length of nearly one thousand miles, of which eight hundred and ninety-three miles belong to the State. The connection with rivers and small lakes makes the whole distance now navigated by New York canal boats about 1,350 miles. On the twenty canals owned by the State are 565 stone locks, which, if placed in a continuous line, would extend nearly seventeen miles; and the bridges over these canals, if placed end to end, would form a line of equal length. The Erie canal, seventy feet wide and seven feet deep, is carried over several rivers and large streams on stone aqueducts of unequalled magnitude. Some idea may be formed of the business done on the New York canals by the following official statements:—

From 1859 to 1866, inclusive, 12,850 canal boats were built and registered, having a carrying capacity of 1,291,497 tons. During these years the aggregate movement on all the canals amounted to 39,433,625 tons. For twenty years preceding 1867 the tolls collected amounted to $65,815,411; the yearly average being $3,090,770. After deducting the cost of maintenance, the average annual

surplus revenue from the canals was found to exceed $2,319,500. From 1854 to 1865, inclusive, the average freight paid for moving one ton one mile on the canals, was nine mills and one-tenth of a mill, while the average freight paid during the same time for moving one ton one mile on the New York Central and Erie Railroads, was $2\frac{41}{100}$ cents, showing that during those years the cost of transportation on railways was nearly three times greater than that on our canals. Boats carrying 210 tons burden are now used on the Erie canal; the enlarged locks being eighteen feet wide and two hundred and ten feet long between the quoins. The boats are mostly moved by animal power, at a cost of thirty-eight cents each per mile, except on the rivers and lakes, where they are taken in tow by steamboats. The average speed of canal boats of the largest class moved by horses does not exceed two miles an hour, and as only three horses can be employed with advantage to each boat, it follows that any further increase on the size of canal boats would involve a corresponding decrease in speed when moved by animal power. According to the able report for 1868 by the Hon. Van R. Richmond, New York State Engineer and Surveyor, the resistance to be overcome in moving a loaded canal boat at a speed of two miles per hour, calculated from Dubuat's formula, as modified by D'Aubisson, is 428 pounds. The force required to develop the standard value of a horse-power at two miles per hour is $187\frac{1}{2}$ pounds; deducting one-sixth for oblique action, leaves the force exerted in the direction of the boat's motion equal to $156\frac{1}{4}$ pounds. From experiments made in France in towing barges on the Languedoc canal, it was found that ordinary horses exerted an average effort of $143\frac{1}{2}$ pounds for six consecutive days, at a speed of two miles per hour. Consequently an Erie canal boat, which partakes of the general build of the Languedoc barges, would require three horses to move it at the rate of two miles per hour. The resistance of a vessel varies as the square of its speed, and the power to move it varies as the cube of its speed. This law seems to have been overlooked by some of those who have attempted to move canal boats at comparatively high speed by means of steam power. They have recognized the truth of only a part of the proposition, namely, that the resistance varies as the square of the speed; that is to say, if a boat requires eight horses to overcome the resistance at four miles an hour, to double its speed would require four times eight or thirty-two horses; yet it is evident that this power must be applied while the boat is moving

double the distance first made, therefore the number thirty-two must be doubled, which gives sixty-four horses as the measure of power required to move the boat at the rate of eight miles per hour. This law, however, cannot be strictly true for all forms of vessels, and in navigating canals there are other conditions which modify the result, as, for instance, the wave of displacement, which rising high in shallow water would seriously impede a vessel, but were its form so improved as to allow the water to begin to close in when only one-third of her length had passed, and were its speed at the same time increased to a certain point, this wave of displacement would be brought into such relative position that it would no longer impede the vessel. However, the carrying capacity of a canal boat being paramount, its form must not be modified so as to favor increased speed; thus with this class of vessels the law will still hold good, to double the velocity the propelling power must be increased eightfold. If a loaded canal boat is moved at the rate of two miles an hour with three horses, and at the rate of four miles an hour with twenty-four horses, the obvious deduction is that it is impracticable to move such boats by horse-haulage at the rate of three miles per hour, and quite as impracticable to move them by steam power at a speed greater than four miles an hour.

The plan of moving several canal boats by one steam tug is objectionable, because the whole moving power is concentrated at one place, and acts upon a very limited quantity of water. The same power divided into four equal amounts, and acting on four times the quantity of water would be more effective. Such boats are most liable to delays, and are utterly helpless when detached from the steam-tug.

The successful navigation of canals seems to me to depend on the following conditions: —

1. Each boat should be automatic, that is to say, self-propelling.

2. The build of the boat should be such as to give it the greatest carrying capacity.

3. To economize space and power, the boiler and engine should be small and capable of moving the boat, when loaded, at an average speed of three miles an hour. This rate is about double the present average speed of loaded boats.

4. The propelling power should act directly against the water, and not against the bottom or sides of the canal.

5. If we turn to nature for lessons in propelling, we observe

that the slow-moving fish of our fresh-water streams have broad tails bounded by a nearly vertical line; while those remarkable for speed have v-shaped tails, the extremities of which are capable of very quick motion. Applying this principle to slow-moving boats we infer that a quick motion is not so essential as a large area of propelling surface.

6. The width of the boat and its draft should only limit the extent of water against which the propelling surface should act.

7. The boat should be made more obedient to the helm by enlarging the rudder surfaces, and arranging them so as to act on shallow water more efficiently than by the common method. These conditions would be fulfilled for the most part by building the boat with four sterns, and placing behind each a propeller; or by giving the boat a scow-shaped stern, and arranging behind it four screw propellers, placed side by side and nearly as deep in the water as the bottom of the boat, from which would project iron bars for their protection. The locks being eighteen feet wide, the propeller blades could be nearly four feet six inches in diameter, and whether the boat were light or loaded these propellers would act on the water under the best possible conditions. Behind each of these propellers should be placed a balanced rudder, which, under these conditions, could be made one-fourth lighter than usual; and the tiller of each should be connected by a movable joint with one bar extending nearly across the boat, behind which the steersman could guide the boat by only exerting strength sufficient to overcome the friction of the apparatus.

A boat embracing the improvements here suggested has not yet been constructed; but from careful estimates based on reliable data, I feel warranted in saying that such a boat, when loaded, could be moved at a speed of three miles an hour, with an expenditure not exceeding that now incurred in towing a similarly loaded boat at the rate of two miles an hour by means of horses. The saving thus effected would be between one and two million dollars per annum, on the present business of the canal. A large portion of the carrying trade has been diverted from canals, solely on account of the time consumed in transportation; we may reasonably infer that an acceleration of speed of about fifty per cent would greatly increase the amount of goods transported by these cheap modes of conveyance, and thus correspondingly increase the revenue which the State derives from its canals.

TITLES

OF

COMMUNICATIONS.*

A. MATHEMATICS, PHYSICS, AND CHEMISTRY.

1. Some New Applications of the Graphical Method. By Edward C. Pickering.

2. An Examination of the Doctrine of Atomicities. By F. W. Clarke.

3. A Description of a New Apparatus for illustrating the Precession of the Equinoxes. By James Bushee.

4. To whom is due the Credit of the Most Important Application of Steam as a Motive Power. By Clinton Roosevelt.

5. Researches in Electro-Magnetism. By Alfred M. Mayer.

6. Unpublished Experiments of Prof. W. B. Rogers on the Influence exerted by the Presence of Carbonic Acid in Gas on its Illuminating Power. By Frederick E. Stimpson.

7. The Connection between Solar Spots, Terrestrial Magnetism, and the Aurora Borealis. By Elias Loomis.

8. A Theory of the Constitution of the Corona of the Sun. By Simon Newcomb.

9. The Conditions of Stable Equilibrium in Atomic Orbits. By H. F. Walling.

* The following papers were also read; of some, no copy has been received for publication; of others, it was voted that the title only should be printed. No notice, *even by title*, is taken of articles not approved.

10. The Chemistry of the Bessemer Process. By C. E. Dutton.

11. On the Illumination of Binocular Microscopes, with Proposal for New Diaphragm-stop. By R. H. Ward.

12. On the Composition of the American Opium. By H. B. Nason.

13. Description of a New Meteorograph, for the Automatic Registration of Meteorological Phenomena. By G. W. Hough.

14. Remarks on the Total Fluctuation of the Barometric Column. By G. W. Hough.

15. Relations existing between Temperature, Pressure, Wind, and Rain-fall, as indicated by Automatic Registering Instruments. By G. W. Hough.

16. On the Rate of the Dudley Observatory Sidereal Clock for Two Years. By G. W. Hough.

17. On Improved Facilities for transmitting Heat from one Fluid to another. By S. D. Tillman.

18. On the Present Aspects of Organic Physics. By Henry Hartshorne.

19. Gaseous and Liquid Rings. By E. N. Horsford.

20. Acid Reaction of Tribasic Phosphate of Lime. By E. N. Horsford.

21. On the Possibility of a Limit of Visible Magnitude. By F. A. P. Barnard.

22. On a New Form of Binocular Microscope. By F. A. P. Barnard.

23. On the Testimony of Ancient Eclipses in regard to the Uniformity of the Earth's Rotation. By J. N. Stockwell.

24. On the Survey of the Northern Heavens instituted by the German Astronomical Society. By T. H. Safford.

25. On Solar Prominences and Spots observed with the Spectroscope during the Past Year. By C. A. Young

26. Some Account of Progress in the Investigation of the Laws of Winds. By J. H. Coffin.

27. Remarks on Stereoscopic Vision as applied to the Microscope. By R. H. Ward.

28. The Solvent Power of Anhydrous Liquid Ammonia. By Charles A. Seely.

29. On the Structure of the Scale of Podura Plumbea. By F. A. P. Barnard.

30. On the Brightness appearing on the Limb of the Moon's Image, in Photographs of Solar Eclipses. By F. A. P. Barnard.

31. On an Improved Form of Solar Eyepiece. By S. P. Langley.

32. Note on the Calculus of Affected Quantity. By E. B. Elliott.

33. Some Remarks on a Pocket Microscope and Telescope combined. By Josiah Curtis.

34. Some Remarks on Nobert's Lines, with Particular Reference to Dr. Woodward's Photographs. By R. H. Ward.

35. The Universal Method of Approximation. By Thomas Hill.

36. Remarks on a Method of producing very Low Power with the Microscope, with Demonstration. By Edwin Bicknell.

37. Molecular Classification. By George F. Barker.

38. On the Latest Discoveries in regard to the Manufacture of Ice by Mechanical Power. By P. H. Vander Weyde.

39. Further Improvements in the Method of Transmitting, audibly, Musical Melodies by the Electric Telegraph-Wire. By P. H. Vander Weyde.

40. The Relation between the Bands of the Spectroscope and the Musical Scale. By P. H. Vander Weyde.

41. Abstract of Paper on Temperature for Twenty-five Years. By O. W. Morris.

B. NATURAL HISTORY.

1. Mrs. Willard's Theory of Circulation by Respiration. By Mrs. A. L. Phelps.

2. The Terrace Epoch in Michigan. By A. Winchell.

3. On the Relation of Organic Life of the Several Continents to the Physical Character of those Land Areas. By N. S. Shaler.

4. On the Character of the Observations necessary to interpret the Record of the last Glacial Period. By N. S. Shaler.

5. On a Method of collecting certain Geological Facts, adopted by the "Social Science Association." By N. S. Shaler.

6. The Magnetic Wells of Michigan. By A. Winchell.

7. The Porphyries of Marblehead. By Alpheus Hyatt.

8. The Development and Old Age of the Tetrabranchiate Cephalopods. By Alpheus Hyatt.

9. The Genetic Relations of the Arietes. By Alpheus Hyatt.

10. Observations of the Stone used by the Indians within the Limits of Massachusetts in the Manufacture of their Implements, with some Remarks on the Process of Manufacture. By James J. H. Gregory.

11. Geology and Topography of the White Mountains, New Hampshire. By C. H. Hitchcock.

12. Description of a new Trilobite from New Jersey. By C. H. Hitchcock.

13. Last Winter's Occupation of Moosilauke Mountain in New Hampshire. By J. H. Huntington.

14. On the Occurrence of Native Iron, not Meteoric. By H. B. Nason.

15. On the Salt Deposit of Western Ontario. By T. Sterry Hunt.

16. On the Lignites of West America, their Distribution and Economic Value. By J. S. Newberry.

17. On the Sequence and Chronology of the Drift Phenomena in the Mississippi Valley. By J. S. Newberry.

18. On some New Relics and Traces of the Mound Builders. By J. S. Newberry.

19. Notice of the Fossil Plants of the Hamilton and Chemung Groups, with reference to the Source of the Sediments of these Formations. By James Hall.

20. On the Relation of the Onedonta Sandstone and Montrose Sandstone of Vanuxem to the Hamilton and Chemung Groups. By James Hall.

21. Note upon the Rocks of Huronian System on the Peninsula of Michigan. By James Hall.

22. On the Geology of the Delta, and the Mudlumps of the Passes of the Mississippi. By E. W. Hilgard.

23. On some New Generic Forms of Brachiopoda, with Remarks on some Points of their Structure. By W. H. Dall.

24. On the Order Docoglossa of Troschel. By W. H. Dall.

25. Some Remarks on Two Deposits of Diatomaceous Earths recently thrown up by the Sea. By Edwin Bicknell.

26. Sign-Language as illustrative of the Laws of Written and Vocal Language. By G. W. Samson.

27. Evidence of Glacial Action in the Placer and Gulch Gold of California. By E. N. Horsford.

28. Fresh Water Pond overlying a Salt Water Pond in Middlesex County, Mass. By E. N. Horsford.

29. On the Nature of the Foliage of Pines, etc.: a Criticism. By Asa Gray.

30. On some Points in the Stratigraphy and Surface Geology of North Carolina. By W. C. Kerr.

31. A Point in Dynamical Geology. By W. C. Kerr.

32. Probable Origin of the South Carolina Phosphates. By W. C. Kerr.

33. Remarks on Customs of the Waribiara and Blanco Indians in the vicinity of Chiriqui Lagoon, Central America. By J. A. McNiel.

34. Lava-Ducts in Washington Territory. By R. W. Raymond.

35. The Salt Marsh at Silver Peak, Southern Nevada. By R. W. Raymond.

36. Remarks on the Occurrence of the Genus Dithyrocaris in the Hamilton and Chemung Rocks of New York. By James Hall.

37. On a New Locality of Kyanite. By Sanborn Tenney.

38. On Abnormal Vertebræ of the Elephant. By Sanborn Tenney.

39. On some Points in the Geology of Eastern Massachusetts. By Sanborn Tenney.

40. Brief Notes on Hoosic Mountain and Tunnel. By James Hyatt.

41. Guano, the Origin of the Apatite of Rideau, Canada. By E. N. Horsford.

42. On the Subdivisions of the Branch Mollusca. By Theodore Gill.

EXECUTIVE PROCEEDINGS

OF

THE TROY MEETING, 1870.

HISTORY OF THE MEETING.

THE Nineteenth Meeting of the American Association for the Advancement of Science was held at Troy, N. Y., commencing on Wednesday, August 17, and continuing to Wednesday afternoon, August 24.

One hundred and eighty-eight names are registered in the book by members who attended this meeting. One hundred and seventy new members were chosen, of whom one hundred and eleven have already signified their acceptance by paying the annual assessment, and, when practicable, signing the constitution. One hundred and forty-four papers were presented, many of which were read, and some of them discussed at length.

The general sessions of the Association were held in the Court House. The Sections were amply accommodated, partly in the Court House, and partly in the spacious halls of the Willard Female Seminary.

At about 10 o'clock, A.M., on Wednesday, the members were called to order by Col. J. W. Foster, the retiring president, who announced that owing to the illness of Prof. William Chauvenet, President, Dr. T. Sterry Hunt, Vice-President, would preside over the deliberations of the Convention. Mr. F. W. Putnam, of Salem, was nominated as General Secretary of the meeting, and unanimously elected. The Divine blessing was then invoked by Chancellor Ferris of the University of New York.

The Association was then introduced to His Honor Uri Gilbert, Mayor of the city, by Hon. John A. Griswold, Chairman of the Local Committee, in the following address: —

MR. PRESIDENT, GENTLEMEN, MEMBERS OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE:—

It is my special privilege and pleasure to greet you on this occasion, and to offer you the first salutation of welcome to our city. I do not know whether our Mayor will succeed in calling your attention to any special objects of interest here; and yet I indulge the hope that your visit will not be without some pleasure, as I know it will not be without profit. At all events our rivers and our railroads furnished you means of easy access to come among us, and I shall indulge the hope that it will be no special source of congratulation to you that they may furnish equally easy facilities for going away from us.

We are eminently a busy people. There are few of the residents of Troy who are not willing to bear their portion of the burthens of the day, but considering your presence here, there are, I regret to say, too many who, while willing to bear the burthens, are unwilling to bear the heat of the day. If, then, you meet with a somewhat restricted hospitality it is because so many of our citizens are held at the watering-places and in the shades of the country, whose residences, otherwise, would be thrown open to a most hospitable welcome to you. No doubt we are exposed to be judged wrong under the circumstances, and yet, as one of its citizens, I beg you to consider the time and the season. We have citizens of Troy even in greater number than you may meet, and if you chance to fall upon the congregation of one of our churches of a Sunday, and find it fewer than you had a right to expect, do not suppose that our habits of church-going are in accordance with the representation there.

So, because our school-houses are closed, I beg of you not to infer that we are insensible to the cause of education. We point with some little pride to both school-houses and churches, and I have no doubt the Mayor will call your attention to some of our leading institutions — our Rensselaer Institute, to the presence of whose professors among you I suppose we are more indebted than to any other one cause for your meeting in this city. That institution we point to as the pioneer in this country of its kind. For fifty years it has been sending out its students of practical science, and to-day from all over the civilized world, from every department of life, and from every stage of society, its graduates reflect back credit and honor upon the institution.

So, too, gentlemen, of our Troy Female Seminary, upon the opposite side of the road from where we are now sitting. That is foremost among the institutions of its kind in the country. It, too, bears the hallowed sanctity of time, howbeit its founder and architect has, within the present year, been carried to her final resting place in the shades of our Oakwood. Mrs. Emma Willard went down from among the representative women of the world full of years, and with the blessings and benedictions of those who knew her long, her able, and her beneficent devotion to the cause of a true woman's education.

Our workshops and our factories will of course greet you everywhere. Here you may find being absorbed the minerals of the earth in such huge proportions as to suggest mechanical indigestion, or possibly, what is still worse, the exhaustion of the raw material. And here, too, you will find that science stands side by side with labor; from her halls of education the student of science is transferred to the workshop and factory and the forge, we having recognized the fact that for the greatest progress and the highest development of labor science must be its light and guide.

Need you be told, then, that we shall watch your deliberations with interest and with hope? For we look upon you as toilers in a field the harvest of which is altogether indispensable to the day and the age. What science has done in the past we can all contemplate. The fruits of its great victory lie spread around everywhere. We see how by its application to the lands the earth is made to increase its fruits and give forth more abundantly to the sustenance of man. It guides the hand of sturdy labor to level the mountain and fill up the valley, and place within the grasp of its iron link a continent bounded by oceans. It discloses and utilizes earth's hidden wealth; maps out the heavens, and reveals the secrets of other worlds. Its fiery breath drives to and fro across the seas stately ships laden with humanity, — freighted with the fruits of liberty, progress, and civilization, — while it converts the dark and forever hidden recesses of the ocean into a highway over which travels the electric messenger, announcing to the world the conflict of Empires and the tottering of thrones, or whispering in the eager ear words of tender remembrance, hope, and assurance.

Science does all these things; it gathers the sunbeams and weaves them into pictures of life and beauty; when tyranny covets conquest science is called upon to devise implements of

power, and when liberty is invaded, or threatened, we turn to the arm of science as our protection and defence.

While, gentlemen, you will continue to thrust upon an astonished world the dazzling achievements of your labors, it is to the utilization of science, if I may be permitted the expression, that I look for the greatest good — its application to the practical. Constantly science is becoming more and more interwoven with labor, and recognized as more and more indispensable to the guidance of the strong arm and the skilful hand.

It may be, gentlemen, that some of you may, at times, feel that the paths you have chosen are not the shortest and the most direct to worldly wealth and power, but remember that performing your duties faithfully you will have the consolation of believing that the world, after you shall have left it, will be better for your having lived in it.

We bid you Godspeed in your career, and would fain offer you words of encouragement and hope. And now let me discharge the agreeable duty devolving upon me, perhaps too long deferred, and introduce you, gentlemen of the American Association for the Advancement of Science, to the citizens of Troy through our esteemed and justly honored Mayor. Into his hands I therefore place your interests and your presence during your visit.

Mayor Gilbert then welcomed the Association in these words: —

MR. PRESIDENT AND GENTLEMEN OF THE ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE: —

Coming among us, as you do, from every part of the country — men of education, men of culture and of science, men who mould and shape the thoughts of their fellow men, men whose deep research into the hidden things of nature brings light out of darkness and order out of chaos, — we hail your coming with pride and with pleasure. And on this occasion it becomes my agreeable duty, in behalf of my fellow citizens, to present to you their most cordial and hearty welcome, and to express the hope that your meeting here may do much to promote the objects of your Association.

Although a small city, and few in numbers compared with many cities where you have assembled, we are not without the hope that beside the social intercourse and the pleasant reunion of men in the same pursuits, all having the same great object — the advancement of science — you may find among us much to interest and to

aid in the furtherance of these pursuits, and to render your stay with us both profitable and pleasurable.

In accordance with enactments of the State Legislature, our children are well provided with the advantages of common schools from the primary departments through the several gradations to the High School, in which the pupils are prepared for a collegiate course or the more active business of life. The Troy Female Seminary, not unknown throughout the United States, was established in Troy almost contemporaneously with its existence as a city. In this (the Willard Seminary) thousands of young ladies have received an education in the higher branches of science, and graduated with much honor to themselves as well as to this noble institution, and have gone forth, many of them, to establish other schools, and to impart to others in all parts of the country the instruction here received. Our Polytechnic School I scarcely need mention, as most of you, gentlemen, are familiar with its character, its objects, and the influence it has long exerted and is still exerting in the scientific world. The pioneer of its kind in this country, it has thus far without endowment held its position in the front rank of the scientific and practical schools in the United States. Many of you have doubtless availed yourselves of its advantages, and are in your professional life practical illustrations of the superior benefits conferred in its full course of study. Its session having just closed, its students are for the time absent, but its doors will be open to all, and all will be welcome to its halls, its laboratory, its cabinet, and whatever there may be of interest to the professor or student in the practical sciences.

Men of science will be pleased to visit our iron and steel works, — works first in importance in our city, first in importance of their kind in the State, and holding only a secondary position of magnitude of their kind in the Union. At the former you may watch the progress from the crude ore to the refined bar, and by the aid of ingenious and complex machinery to the complete and finished horseshoe, the railroad spike and chair, as well as to the many other productions pertaining to this extended branch of business.

At the Bessemer Steel Works you will also behold the rough pig of iron suddenly transformed to the ingot of steel, and thence to the finished rail, which is hereafter to form the main dependence for safety and permanence in the construction of our railways. In visiting these works I am sure you will be welcomed, and receive the polite attention of the proprietors and agents.

I will mention one other manufacturing establishment which I know in the minds of many is intimately associated with the name of Troy, — that of Messrs. Gurleys, makers of civil engineers' and surveyors' instruments, a business closely identified with the scientific progress and material development of our country. This establishment, founded in 1848, for many years the largest of its kind in the Union, has acquired a national reputation. The members of the Association interested in this department of science will find instruction and pleasure in a visit to these works.

There are many other manufacturing establishments of note in our city. In fact, we are a manufacturing community; and for the continuance of these and their further development we rely much for the prosperity of Troy. At the head of tide-water, and the outlet of the Erie and Champlain canals, our commerce is an important element in our growth and success. And not the least of the advantages of our position is the concentration of railroads in our city, connecting us directly with all the railroad interests, North and West, as well as in the middle and Southern portions of the State.

Again I say to you, gentlemen, we are pleased to receive you, and repeat to you our cordial welcome.

President T. Sterry Hunt responded, and in the name of the American Association for the Advancement of Science he begged to return the cordial thanks of the members for the invitation to come here, and for the cordial reception they had received from the citizens of Troy. He then recounted briefly the history of the Association. It was organized in 1840, and was first devoted to the advancement of the study of geology and natural history. In 1848 it was recast upon a broader basis, the mathematical and physical sciences were comprehended in its objects, and its present name given to it. During the four years of the rebellion its sessions were interrupted. In 1866 it was re-organized at Buffalo, and a yearly meeting was resolved upon in place of the semi-annual sessions formerly held. When we look back upon the past we regret that so many of the fathers of the Association are not with us to-day. Silliman, Hare, two of the brothers Rogers, Bache, Hitchcock, and Emmons are no more. Sickness holds others in its bonds. Professors Dana, W. B. Rogers, and Agassiz are unable to be with us on account of delicate health, but there are young men here to-day who will doubtless represent, not without honor,

the sciences to which the latter has devoted his life. Professor Joseph Henry is in Europe, where he is receiving a warm welcome from the scientists of Berlin, Vienna, and other capitals.

It must be clearly understood that the Association is not a close society, designed only for the select few. It is highly democratic, it wishes to enroll all who take an interest in science, and assures them of a kindly welcome. We hope to add to our numbers largely from the students and amateurs of science in Troy. This is the fourth place where we have met in New York State — New York City, Albany, Buffalo, and to-day Troy — and it is proper the great Empire State should thus be considered by the representatives of American science. It was among the first of the States of our Union to organize a complete system of geological and natural history surveys of its territory, and it is, therefore, classic ground for the student of these sciences. To Troy we look with interest for the success of our meeting on account of the Rensselaer Polytechnic School, the pioneer scientific school in America, which, having seen half a century of prosperity, is now more active than ever, with its corps of young, able, and enthusiastic professors. This institution was founded by one who was the father of American geology, Professor Amos Eaton. I see two of its most distinguished graduates here to-day, Professor James Hall and Mr. E. N. Horsford. To the chemist and metallurgist the extensive iron works here offer a field for investigation such as few other places present. Here applications of science are employed in the conversion of the ore, until the manufacture of iron is no longer one of crude empiricism. We have here, also, the Bessemer Steel Works, in which may be seen processes that present great attractions to the chemist and physicist. Their importance is not limited to the production of steel, but, when studied by the aid of the spectroscope, Mr. Griswold's converters throw new light upon the chemical and physical constitution of the sun and the farthest nebulæ. I mention these things to show that the American Association for the Advancement of Science does not overlook the practical affairs of life.

At the close of the President's address the Association proceeded to business. Six additional members of the Standing Committee were elected by ballot, according to the requirement of Rule 4 of the Constitution. The names of those chosen are printed elsewhere with the names of the other members of that committee.

Later in the session the Association voted to hold its next

meeting at Indianapolis, Indiana, beginning on Wednesday, August 16, 1871. The officers elected for the next meeting are:—

Prof. ASA GRAY, of Cambridge, *President;* Prof. GEORGE F. BARKER, of New Haven, *Vice-President;* F. W. PUTNAM, Esq., of New Haven, *General Secretary;* W. S. VAUX, Esq., of Philadelphia, *Treasurer.* Prof. JOSEPH LOVERING, of Cambridge, was elected at Salem *Permanent Secretary* for another term of two years, commencing with the Troy Meeting.

On Thursday evening, August 18, the address of Col. J. W. Foster, the retiring President, was given in the First Presbyterian Church. General sessions were also held at other times, when papers of interest to all the members of the Association, as well as to the public, were read.

On Friday afternoon, the members of the Association and their ladies, accompanied by many ladies and gentlemen of Troy, by invitation of the Albany Institute, took the steamer provided for them, near the foot of Broadway, and proceeded to Albany. There they visited the Dudley Astronomical Observatory, and enjoyed the hospitality of its trustees. Afterwards, they had an opportunity to examine the rich and various collections in the State Museum of Natural History. At half-past seven they assembled in the State Library, where they were received by the officers and members of the Albany Institute, and other citizens of Albany. After an elegant entertainment and some informal addresses they returned to Troy, by steamer, at 10 o'clock, under the bright light of an aurora. Monday was mostly devoted to an excursion, by special train, to Saratoga, where, after some hours spent in scientific explorations or social enjoyment, according to the individual tastes of the members, all dined together in Congress Hall. The Mayor and other prominent citizens of Troy, and their ladies, as also the members of the Local Committee and their families, contributed largely by their presence to the pleasures of an occasion for which the citizens of Troy had made such generous provision.

On Thursday evening the members of the Association, and the ladies who accompanied them, were entertained at the residence of Mayor Gilbert; and on Monday evening they were present at a reception given by J. M. Francis, Esq. Individually, many members in attendance on this meeting were the recipients of much kindness and hospitality from citizens and societies of Troy, for which they will always retain a grateful remembrance.

The proprietors of the Bessemer Steel Works, the Burden Iron Works, the Albany Iron Works, and the Rensselaer Iron Works opened their doors to the members of the Association, and gave them ample opportunity for witnessing all their interesting processes of manufacture. Gen. P. V. Wagner, commanding the United States Arsenal at Watervliet, the largest arsenal in the country, invited the members of the Association to visit the grounds and buildings of this establishment, and gave them his personal attention whenever it was practicable. Many other places of interest in the neighborhood of Troy were visited by detached parties, such as the Rensselaer Polytechnic Institute of Troy, and the Harmony Mills of Cohoes. The vicinity of these mills is interesting as including the beautiful falls of the Mohawk, and as having once entombed the remains of the great mastodon, now in the Museum at Albany.

RESOLUTIONS ADOPTED.

Resolved, That a committee of three be appointed to memorialize Congress on the importance of establishing an observatory, and maintaining a scientific corps, for a year or more, at one of the highest points on the Pacific Railroad, and particularly at the Eastern Rim of the Utah Basin.

Resolved, To accept the invitation from San Francisco for the meeting of 1872, provided the necessary arrangements can be made; and that a committee be chosen to arrange for such a meeting, and report at the next meeting in Indianapolis.

Resolved, That the printed volume of Proceedings be sent, immediately on publication, free of postage, to each member who has paid the assessment of three dollars for the meeting to which the volume relates.

VOTES OF THANKS.

Resolved, That the thanks of the Association be returned to the Mayor and Common Council of the city of Troy for their kind liberality in granting the use of the Court Room and adjoining apartments for the sessions of the Association.

Resolved, That the thanks of the Association be presented to the citizens of Troy for their liberality and courtesy in arranging the delightful excursion of Monday last to Saratoga Springs, and for the generous provision made for the entertainment, enjoyment, and comfort of the members on that occasion.

Resolved, That the thanks of this Association be hereby presented to the pastor, officers, and congregation of the First Presbyterian Church of this city, for the generous use of their house of worship, in which our meeting was held to hear the address of our last President.

Resolved, That the thanks of this Association are due to the managers of the Burden Iron Works and the Bessemer Steel Works, of this place, for their courtesy in permitting us fully to inspect the processes therein carried on,—processes among the most novel and interesting in the metallurgy of iron.

Resolved, That this Association hereby expresses its thanks to Mr. John H. Willard, of the Troy Female Seminary, for the excellent accommodation he has afforded its sections in his commodious building; and to him, as well as to Mrs. Willard, for the hospitality and courtesy which they have so uniformly extended to its members.

Resolved, That the thanks of the Association be given to the members of the Troy Club for the use of their convenient and beautiful rooms, so liberally offered, and so richly enjoyed.

Resolved, That the thanks of the Association are eminently due to the Trustees and Faculty of the Rensselaer Polytechnic Institute for the efforts they have made in promoting the interest of the Association, and contributing to the pleasure and convenience of its members at this meeting; and that their respectful thanks are likewise tendered to the Young Men's Association for the use of their Reading Room and Library.

Resolved, That the cordial thanks of this Association are due to the members of the Albany Institute for their kind reception and generous entertainment, and for the opportunity to visit the Dudley

Observatory, the State Museum, the State Library, and the private collections of Professor James Hall.

Resolved, That the Association tenders its sincere thanks to the members of the Local Committee, and especially to the Chairman, Hon. John A. Griswold, and to the Secretaries, Messrs. H. B. Nason and Benjamin H. Hall, for the foresight and good judgment with which their arrangements for the present meeting were effected, and for their unremitting attentions and efficient services in behalf of the Association during the progress of the meeting.

Resolved, That the thanks of this Association be given to the reporters of the press for their attention to our proceedings, and for the accurate account which they have given to the community.

Resolved, That the thanks of the Association be voted to President Hunt and to Secretary Putnam, for the able and gentlemanly manner in which they have conducted the business of the nineteenth meeting.

Resolved, That the thanks of the American Association for the Advancement of Science be returned to the following Railroad Companies, for their courteous and valuable contribution to the interests of the Association in the matter of free return tickets or reduced rates to its members: —

Rensselaer and Saratoga.
Boston and Albany.
Boston and Providence.
Richmond and Petersburg.
Richmond, Fredericksburg, and Potomac.
Cincinnati and Indianapolis Junction.
Philadelphia and Reading.
Louisville and Nashville, and Memphis and Louisville Railroad line.
Great Western of Canada.
New York and Oswego Midland.
Nashville and Chattanooga, and Nashville and North Western.
Louisville and Nashville.
Fitchburg.
Erie.
Troy and Boston.
Champlain Transportation Co.
Wilmington, Columbia, and Augusta.
New Bedford and Taunton.
Utica and Black River.
New Jersey Southern.

REPORT OF THE PERMANENT SECRETARY.

The following report comprises the business which has been done for the Association during the interval between the first day of the Salem Meeting (August 18, 1869), and the first day of the Troy Meeting (August 17, 1870).

An unusually large number of copies of the Chicago volume of Proceedings have been distributed to members. The list of Foreign Academies to which the Proceedings are sent is increased every year. The Salem volume was ready for distribution on the first day of the present month. The delay proceeds partly from the necessity of sending proof-sheets over the whole country, some of which may not find the authors at home; and partly, from the neglect of authors to furnish a copy of their papers, at an early date, for publication. Many valuable papers are not sent at all, and some arrive too late even for the requirements of the slowly printed volume.

The financial condition of the Association is as follows: —

Between August 18, 1869, and August 17, 1870, the income of the Association was twenty-two hundred and seventy-eight dollars ($2,278).

Of this amount seventy-five dollars and fifty cents ($75.50) accrued from the sale of the printed Proceedings, and the remainder from the admission fees and the annual assessments.

The expenses of the Association, during the same interval, amounted to seventeen hundred and sixty-one dollars and seven cents ($1,761.07), which may be apportioned thus: —

Cost of paper, printing, and binding for the volume of Salem Proceedings, and expense of its distribution	$1,192.10
Charges connected with the Salem Meeting	20.00
Salary of the Permanent Secretary (five hundred dollars)	500.00
For circulars, postage, stationery, express, etc.	48.97

The particular items may be found in the cash account of the Secretary, which is herewith submitted as a part of his report. The balance in the Treasury of the Association, August 17, 1870, is seventeen hundred and forty-two dollars and two cents (1,742.02).

JOSEPH LOVERING,
Permanent Secretary.

TROY, August 17, 1870,

CASH ACCOUNT OF THE PERMANENT SECRETARY.

DR. AMERICAN ASSOCIATION *in account with* JOSEPH LOVERING. CR.

J. W. Harris's bill as clerk	$20.00	Balance from last account	$1,225.09
Postage	70.63	Assessments (from No. 452 to No. 895 of Cash Books) and from the Sale of Proceedings	2,278.00
Express	18.92		
Printing circulars	4.50		
Stationery	2.17		
Discount	.75		
Wrapping paper and twine	1.25		
Letter-book	2.00		
Composition of Salem Proceedings	719.00		
Paper and press-work	325.60		
Paper for cover	5.75		
Printing cover	3.50		
Binding	56.00		
Wood-cuts	31.00		
Salary of Permanent Secretary	500.00		
	$1,761.07		
Balance to next account	1,742.02		
	$3,503.09		$3,503.09

STOCK ACCOUNT OF THE PERMANENT SECRETARY.

Volumes Distributed or Sold, since the Report in Vol. XVIII.

VOLUMES.	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.	XI.	XII.	XIII.	XIV.	XV.	XVI.	XVII.	XVIII.
Distributed to Members																		1
Harvard College																		1
Boston Public Library																		1
American Academy																		1
Boston Nat. Hist. Society																		1
Connecticut Academy of Science																		1
Yale College																		1
Brown University																		1
Providence Athenæum																		1
Boston Athenæum																		1
Smithsonian Institute																		1
Columbia College																		1
Astor Library															1	1	1	1
Chicago Academy of Science	1	1	1	1	1	1	1	1	1		1		1			1		1
Foreign Societies *						1	1	1			1	1	1	1			7	73
Sold																		
Total	1	1	1	1	1	2	2	2	1		2	1	2	1	1	2	8	87
Balance, July, 1870	41	95	230	215	417	276	514	836	936	875	811	931	991	1113	572	458	498	
Received from Binders																		937
Balance, May, 1871	40	94	229	214	416	274	512	834	935	875	809	930	989	1112	571	456	490	850

* See pages 379, 380.

LIST OF EUROPEAN INSTITUTIONS TO WHICH COPIES OF VOLUME XVIII. OF THE PROCEEDINGS OF THE AMERICAN ASSOCIATION WERE DISTRIBUTED BY THE PERMANENT SECRETARY IN 1870.

Stockholm, — Kongliga Svenska Vetenskaps Akademien.
Copenhagen, — Kongel. danske Vidensk. Selskab.
Moscow, — Société Impériale des Naturalistes.
St. Petersburg, — Académie Impériale des Sciences.
„ „ Kais. Russ. Mineralogische Gesellschaft.
„ „ Observatoire Physique Centrale de Russie.*
Pulkowa, — Observatoire Imperiale.
Amsterdam, — Académie Royale des Sciences.
„ Genootschap Natura Artis Magistra.
„ Zoölogical Garden.
Haarlem, — Hollandsche Maatschappij der Wettenschappen.
Leyden, — Musée d'Histoire Naturelle.
„ The University Library.†
Utrecht, — Institut Royal Météorologique des Pays-Bas.†
Altenburg, — Naturforschende Gesellschaft.
Berlin, — K. P. Akademie der Wissenschaften.
„ Gesellschaft für Erdkunde.
Bonn, — Naturhist. Verein der Preussisch. Rheinlandes, &c.
Breslau, — K. L. C. Akademie der Naturforscher.
Brünn, — Naturforschenden Vereins.
Dresden, — K. L. C. Deutsche Akademie der Naturforscher. ‡
Franckfurt, — Senckenbergische Naturforschende Gesellschaft.
Freiburg, — Königlich-Sächsische Bergakademie.
Göttingen, — Königl. Gesellschaft der Wissenschaften.
Hamburg, — Naturwissenschaftlicher Verein. §
Hannover, — Die Naturhistorische Gesellschaft.
Königsberg, — Königliche-Physikalish Okonomischen Gesellschaft.
Leipsic, — Königlich-Sächsische Gesellschaft der Wissenschaften.
Munich, — K. B. Akademie der Wissenschaften.
Prag, — K. Böhm. Gesellschaft der Wissenschaften.
Stuttgart, — Verein für Vaterländische Naturkunde.
Vienna, — K. Akademie der Wissenschaften.
„ K. K. Geographischen Gesellschaft.
„ Geologischen Reichsanstalt.
„ Osterreichische Gesellschaft für Meteorologie.

* Also, Volumes vi., vii. and viii. † Also, Volume xvii.
‡ Also, Volumes xiii. and xiv. § Also, Volumes xii. and xiii.

Vienna, — K. K. Zoologisch-Botanische Gesellschaft.
„ Verein zur Verbreitung Naturwissensch. Kentnisse.
Württemburg, — Der Verein für Vaterländische Nuturkunde.
Basel, — Naturforschende Gesellschaft.
Bern, — Allgemeine Schweizerische Gesellschaft.
„ Naturforschende Gesellschaft.
Genève, — Société de Physique et d'Histoire Naturelle.
Lausanne, — Société Vaudoise des Sciences Naturelles.*
Neuchatel, — Société des Sciences Naturelles.
Zurich, — Naturforschende Gesellschaft.*
Bruxelles, — Académie Royale des Sciences, &c.
Liege, — Société Royale des Sciences.
Cherbourg, — Société Académique.
Dijon, — Académie des Sciences, &c.
Lille, — Société Nat. des Sciences, de l'Agriculture, et des Arts.
Montpellier, — Académie des Sciences et Lettres.
Paris, — Institut de France.
„ Société Philomatique.
„ Société Météorologique de France.
Turin, — Accademia Reale delle Scienzie.
Rome, — Osservatorio Astronomico del Collegio Romano.*
Madrid, — Real Academia de Ciencias.
Cambridge, — Cambridge Philosophical Society.
Dublin, — Royal Irish Academy.
Edinburgh, — Royal Society.
Liverpool, — The Literary and Philosophical Society.
London, — Board of Admiralty.
„ East India Company.
„ Museum of Practical Geology.
„ Royal Society.
„ Royal Astronomical Society.
„ Royal Geographical Society.
„ Royal Institution of Great Britain.*
Manchester, — Literary and Philosophical Society.
Newcastle-upon-Tyne, — The Tyneside Naturalist's Field-Club.
„ Nat. Hist. Soc. of Northumberland, Durham, &c.*
Oxford, — Radcliffe Observatory.*
Batavia, — Societé des Arts et des Sciences.

* Also, Volume xvii.

REPORTS.

President F. A. P. Barnard, from the Committee on Weights and Measures, made a verbal report, and requested that the committee be continued until the next meeting of the Association, and the recommendation was voted by the Association.

Report on the Microscopes and Microscopical Apparatus exhibited at the Meeting of the American Association for the Advancement of Science, at Troy, N. Y., August, 1870.

In accordance with the custom initiated at the Salem meeting last year, the local committee for the Troy meeting provided suitable rooms for the preservation and use of instruments sent or brought by members and others for the use of the sub-section, and notified members of the arrangement by a special notice appended to the second circular.

An abundance of apparatus was furnished by members to illustrate their discussions, and for the general work of the sub-section. First class stands, mostly binocular, and full sets of accessories were furnished by President F. A. P. Barnard, Dr. R. H. Ward, Mr. E. Bicknell, Prof. H. B. Nason, and others. Very low-power objectives, three to five inch, were deservedly popular. The use of immersion objectives for all high powers seemed to be assumed by all members as a settled question. Few members, on the other hand, fell into the present fashion of high-power objectives, — preferring to use lenses of one-fifteenth or one-sixteenth inch, and downward, and gain greater amplification by other means than by reducing the nominal focus of the objective. The following novelties require particular mention: —

President F. A. P. Barnard, of Columbia College, New York, demonstrated a newly contrived binocular microscope, a full description of which is published elsewhere, in which the light is separated into two pencils by double refraction, and which cannot fail to be a valuable addition to the resources of working microscopists.

Dr. Josiah Curtis, of Boston, exhibited a micro-telescope, or microscope and telescope combined, made to his order by Tolles. It

is an ordinary Cutter's clinical microscope, fitted with an extra tube carrying an object-glass of one inch linear aperture and six inches focus, to which object-glass the compound microscope acts as an erecting eye-piece. Furnished with a proper support, this makes an admirable pocket telescope, defining well at powers of forty or fifty diameters.

Dr. R. H. Ward, of Troy, N. Y., exhibited a variety of illuminating apparatus, in which a horizontal slit was substituted for the circular diaphragm openings ordinarily used. By this means an illuminating pencil is obtained, which is wide horizontally and narrow vertically to any extent that may be desired. The contrivance is specially designed for use with Wenham's binocular, but may be used to advantage on other stereoscopic microscopes. It was shown as applied to microscopes without accessories, to the spotted lens used for transparent illumination of both fields under medium powers, to objectives used as illuminators, and to the elaborate achromatic condensers of Ross, Powell, and Leland, &c. But it was most readily applied to an eye-piece used as condenser, or to the Webster condenser and similar combinations. A horizontal slit of adjustable width was obtained by a pair of shutters, or by a wedge-shaped opening gradually passed under the condenser, the length of the slit being controlled by Collins's graduating diaphragm, or by Brown's iris diaphragm, or Zentmayer's graduating diaphragm. By these means transparent objects were shown in Wenham's binocular instrument, under lenses of as high power as one-eight inch, and of angular aperture as high as 130°, with both fields fully, softly, and evenly lighted, and free from unpleasant glare of light or distortion of image. A one-fourth of 75° or a four-tenths of 120° can be as easily worked, stereoscopically, in this way, as a one-inch of 25°. Thus the stereoscopic microscope may be almost as readily used in the study of the tissues of animals and the coarser diatomes as in the general structure of plants, the organs of insects, or the larger protozoa.

Dr. Ward also exhibited a variety of class-microscopes, both simple and compound, for the ready demonstration of structure to the class in teaching botany, zoölogy, &c.

Mr. Tolles had mounted a two and one-half inch lens with the society screw on each side of the shoulder, so that it can either be screwed on in the usual position or reversed so as to give, by approaching the eye-piece, about the power of a four-inch lens at the usual distance. Microscopists have been accustomed to gain a

lower power than could be focussed by their rack by screwing a low objective into the draw-tube, and focussing upon the object through the empty nose-piece. The new plan of a reversible mounting is more convenient, and is applicable to instruments that have no draw-tube. Unfortunately, it cannot be used with the ordinary binoculars.

Mr. Tolles has also arranged a four-inch objective, in which a short working focus is obtained by a reducing lens in the rear. This reducing lens, for convenience, is mounted in a sliding tube and gives, when pushed in, a fair three-inch power. As a four-inch the combination is extremely good.

Mr. E. Bicknell, of the Museum of Comparative Zoölogy, Cambridge, Mass., applies this expedient to ordinary objectives, placing in the draw-tube, instead of the concave amplifier sometimes used, an achromatic convex lens as a reducer, with which an extremely low power can be obtained with good definition, flat field, and working focus not inconveniently long. A four and a half or five-inch lens (solar focus) may be used. A low objective of two combinations may be divided, using one part as an objective, and placing the other in the draw-tube.

Dr. Ward had contrived a clinical compressor for use with the microscope of the same name. It is simple, and therefore inexpensive, and can be used with great facility, both for clinical and class use, and for much of the ordinary work of the microscopist. It is not applicable to very fine work, nor to very high powers The two brass plates which hold the thin glass circles separate entirely for arranging the object or cleaning the glass. The upper plate fits into a notch filed in a ledge at the left of the lower, the centering of the two plates being secured by a pin through the lower, and a notch in the upper. The screw which attaches them at the right is permanently fastened in the upper plate by a groove and a pin.

Dr. Maddox's photographs of the Podura scale were exhibited by Dr. Barnard. In these photographs the traditional note of exclamation or goose-quill markings are marked with partial interruptions or transverse lines, suggestive perhaps of the alleged beaded structure.

In the same connection Dr. Barnard exhibited the opake illuminator, suggested by himself for use with high powers. This is an internal Lieberkuhn situated, like Tolles's prism, behind the front combination of the objective. It works exceedingly well with

medium powers, but cannot be introduced for want of room into very high powers. It gives more light than Tolles's prism, and illuminates from any part or all parts of the circumference at will; on the other hand it is less easily applied, requiring the front lens to be mounted in glass instead of brass, and it is inapplicable to large opake objects. It would seem to be most readily applied to single front combinations.

Mr. Bicknell exhibited some brackish and fresh-water diatomes, recently thrown up by the sea at Marblehead, Mass. These are believed to be the first fresh-water or brackish deposits known to exist under the present ocean, and to indicate recent encroachments of the ocean upon the shore line in that vicinity.

Nobert's nineteen-band test-plate, and Dr. Woodward's late photographs of the same were exhibited by Dr. Ward.

Mr. E. B. Benjamin, of New York, exhibited a microscope by Gundlach of Berlin. This was a small and cheap instrument, according to the English and American standard, but really admirable for its neatness of design and finish, and its general excellence of performance.

Beck's popular microscopes (binocular) were exhibited by Mr. C. E. Hanaman, of Troy, N. Y., and others. They have already earned their name in this country.

Mr. Chas. Stodder, of the Boston Optical Works, exhibited Cutter's clinical microscopes and Tolles's students' microscopes, of various degrees of completeness and cost. These, when furnished with suitable lenses, are thoroughly good and useful instruments.

Blankley's neat and convenient tank microscope, made by Swift of London, was exhibited by Dr. Ward.

The cheapest really useful instruments exhibited were Miller's students' microscope, exhibited by F. Miller, of Miller & Bros., New York (who also exhibited first class accessories and choice objects); and Crouch's educational microscope, exhibited by Dr. Ward. These two instruments possess the rare advantage of a body of ample size, the latter one admitting the use of the same eye-pieces as the first class stands.

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Committee to report in relation to Uniform Standards in the Power of Objectives, Eye-Pieces, &c.: F. A. P. Barnard, E. Bicknell, R. H. Ward, C. E. Pickering, O. N. Rood, Josiah Curtis.

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